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# MODES OF MOTION

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## By Professor A. E. Dolbear

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# MODES OF MOTION

OR

## *MECHANICAL CONCEPTIONS*

*OF*

## *PHYSICAL PHENOMENA*

BY

A. E. DOLBEAR

PROFESSOR OF PHYSICS, TUFTS COLLEGE

AUTHOR OF "THE ART OF PROJECTING" "MATTER, ETHER, AND MOTION" "THE TELEPHONE" ETC.

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# MODES OF MOTION;

OR,

## Mechanical Conceptions of Physical Phenomena

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## CHAPTER I

And now we might add something concerning a most subtile spirit which pervades and lies hid in all gross bodies, by the force and action of which spirit the particles of bodies attract each other at neat distances, and cohere if contiguous, and electric bodies operate at greater distances as well repelling as attracting neighboring corpuscles, and light is emitted, reflected, inflected and heats bodies, and all sensation is excited and members of animal bodies move at the command of the will. NEWTON, in *Principia*.

IN Newton's day the whole field of nature was practically lying fallow. No fundamental principles were known until the law of gravitation was discovered. This law was behind all the work of Copernicus, Kepler, and Galileo; and what they had done needed interpretation. It was quite natural that the most obvious and mechanical phenomena should first be reduced; and so the *Principia* was concerned with mechanical principles applied to astronomical prob-

lems. To us, who have grown up familiar with the principles and conceptions underlying them, all varieties of mechanical phenomena seem so obvious that it is difficult for us to understand how any one could be obtuse to them; but the records of Newton's time, and immediately after this, show that they were not so easy of apprehension. It may be remembered that they were not adopted in France till long after Newton's day. In spite of what is thought to be reasonable, it really requires something more than complete demonstration to convince most of us of the truth of an idea, should the truth happen to be of a kind not familiar, or should it chance to be opposed to our more or less well-defined notions of what it is or ought to be. If those who labor for and attain what they think to be the truth of any matter were a little better informed about mental processes and the conditions under which ideas grow and displace others, they would be more patient with mankind; and teachers of every rank might discover that what is often called stupidity may be no more than mental inertia, which can no more be made active by willing than can the movement of a cannon-ball by a like effort. We grow into our beliefs and opinions upon all matters, and scientific ideas are no exceptions.

Whewell, in his *History of the Inductive Sci-*

*ences*, says that the Greeks made no headway in physical science, because they lacked appropriate ideas. The evidence is overwhelming that they were as observing, as acute, as reasonable, as any who live to-day. With this view, it would appear that the great discoverers must have been men who started out with appropriate ideas — were looking for what they found. If, then, one reflects upon the exceeding great difficulty there is in discovering one new truth, and the immense amount of work needed to disentangle it, it would appear as if even the most successful have but indistinct ideas of what is really appropriate, and that their mechanical conceptions become clarified by doing their work. This is not always the fact. In the statement of Newton quoted, he speaks of a spirit which lies hid in all gross bodies, etc., by means of which all kinds of phenomena are to be explained: but he deliberately abandons that idea when he comes to the study of light, for he assumes the existence and activity of light corpuscles, for which he has no experimental evidence; and the probability is that he did this because the latter conception was one which he could handle mathematically, while he saw no way for thus dealing with the other. His mechanical instincts were more to be trusted than his carefully calculated results;

for, as all know, what he called "spirits" is what to-day we call the ether, and the corpuscular theory of light has now no more than an historic interest. The corpuscular theory was a mechanical conception, but each such corpuscle was ideally endowed with qualities which were out of all relations with the ordinary matter with which it was allied.

Until the middle of the present century the reigning physical philosophy held to the existence of what were called imponderables. The phenomena of heat were explained as due to an imponderable substance called "caloric," which ordinary matter could absorb and emit. A hot body was one which had absorbed an imponderable substance. It was, therefore, no heavier than before, but it possessed ability to do work proportional to the amount absorbed. Carnot's ideal engine was described by him in terms that imply the materiality of heat. Light was another imponderable subtance maintained by Sir David Brewster as long as he lived. Electricity and magnetism were imponderable fluids, which, when allied with ordinary matter, endowed the latter with their peculiar qualities. The conceptions in each case were properly mechanical ones *part* (but not all) *of the time;* for when the immaterial substances were dissociated from matter, where they had manifested themselves,

no one concerned himself to inquire as to their whereabouts. They were simply off duty, but could be summoned, like the genii in the story of Aladdin's Lamp. Now, a mechanical conception of any phenomenon, or a mechanical explanation of any kind of action, must be mechanical all the time, the antecedents as well as the consequents. Nothing else will do except a miracle.

During the fifty years from about 1820 to 1870, a somewhat different kind of explanation of physical events grew up. The interest that was aroused by the discoveries in all the fields of physical science — in heat, electricity, magnetism, and chemistry — by Faraday, Joule, Helmholtz, and others, compelled a change of conceptions: for it was noticed that each special kind of phenomenon was preceded by some other definite and known kind; as, for instance, that chemical action preceded electrical currents, that mechanical or electrical activity resulted from changing magnetism, and so on. As each kind of action was believed to be due to a special force, there were invented such terms as mechanical force, electrical force, magnetic, chemical, and vital forces; and these were discovered to be convertible into one another, and the "doctrine of the correlation of the physical forces" became a common expression in

philosophies of all sorts. By "convertible into one another" was meant, that, whenever any given force appeared, it was at the expense of some other force: thus, in a battery, chemical force was changed into electrical force; in a magnet, electrical force was changed into magnetic force, and so on. The idea here was the *transformation of forces;* and *forces* were not so clearly defined that one could have a mechanical idea of just what had happened. That part of the philosophy was no clearer than that of the imponderables which had largely dropped out of mind. The terminology represented an advance in knowledge, but was lacking in lucidity, for no one knew what a force of any kind was.

The first to discover this and to repudiate it were the physiologists, who early announced their disbelief in a vital force, and their belief that all physiological activities were of purely physical and chemical origin, and that there was no need to assume any such thing as a vital force. Then came the discovery that chemical force, or affinity, had only an adventitious existence, and that at absolute zero there was no such activity. The discovery of, or rather the appreciation of, what is implied by the term *absolute zero*, and especially of the nature of heat itself, as expressed in the statement that heat is a mode of motion, dismissed

another of the so-called forces as being a metaphysical agency having no real existence, though standing for phenomena needing further attention and explanation; and by explanation is meant *the presentation of the mechanical antecedents for a phenomenon, in so complete a way that no supplementary or unknown factors are necessary.* The train moves because the engine pulls it; the engine pulls because the steam pushes it. There is no more necessity for assuming a steam force between the steam and the engine, than for assuming an engine force between the engine and the train. All the processes are mechanical, and have to do only with ordinary matter and its conditions, from the coal-pile to the moving freight, though there are many transformations of the forms of motion and of energy between the two extremes.

During the past thirty years there has come into common use another term, unknown in any technical sense before that time; namely, *energy.* What was once called the conservation of force is now called the conservation of energy, and we now often hear of forms of energy. Thus, heat is said to be a form of energy; and the forms of energy are convertible into one another, as the so-called forces were formerly supposed to be transformable into one

another. We are asked to consider gravitative energy, heat energy, mechanical energy, chemical energy, electrical energy. When we inquire what is meant by energy, we are informed that it means ability to do work, and that work is measurable as a pressure into a distance, and is specified as foot-pounds. A mass of matter moves because energy has been spent upon it, and has acquired energy equal to the work done on it; and this is believed to hold true, no matter what the kind of energy was that moved it. If a body moves, it moves because another body has exerted pressure upon it, and its energy is called *kinetic energy;* but a body may be subject to pressure, and not move appreciably, and then the body is said to possess *potential energy.* Thus, a bent spring and a

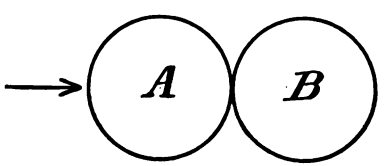



*Fig. 1.*

raised weight are said to possess potential energy. In either case, *an energized body receives its energy by pressure, and has ability to produce pressure on another body.* Whether or not it does work on another body depends on the

rigidity of the body it acts upon. In any case, it is simply a mechanical action, — body A pushes upon body B (Fig. 1). There is no need to assume anything more mysterious than mechanical action. Whether body *B* moves this way or that depends upon the direction of the push, the point of its application. Whether the body be a mass as large as the earth or as small as a molecule makes no difference in that particular. Suppose, then, that *a* (Fig. 2)

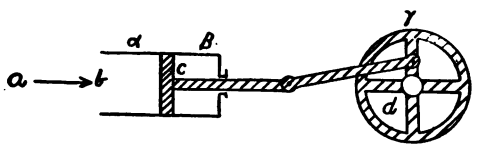



*Fig. 2.*

spends its energy on *b*, *b* on *c*, *c* on *d*, and so on. The energy of *a* gives translatory motion to *b*, *b* sets *c* vibrating, and *c* makes *d* spin on some axis. Each of these has had energy spent on it, and each has some form of energy different from the other; but no new factor has been introduced between *a* and *d*, and the only factor that has gone from *a* to *d* has been motion, — motion that has had its direction and quality changed, but not its nature. If we agree that energy is neither created nor annihilated by any physical process, and if we assume that *a* gave to *b* all its energy, — that is, all its motion,

— that *b* likewise gave its all to *c*, and so on, then the succession of phenomena from *a* to *d* has been simply the transferrence of a definite amount of motion, and therefore of energy, from the one to the other; for *motion has been the only variable factor.* If, furthermore, we should agree to call the translatory motion $\alpha$, the vibratory motion $\beta$, the rotary $\gamma$, then we should have had a conversion of $\alpha$ into $\beta$, of $\beta$ into $\gamma$ (Fig. 2). If we should consider the amount of the transferrence instead of the kind of motion, we should have to say that the $\alpha$ energy had been transformed into $\beta$, and the $\beta$ into $\gamma$.

What a given amount of energy will do depends only upon its *form;* that is, the kind of motion that embodies it.

The energy spent upon a stone thrown into the air, giving it translatory motion, would, if spent upon a tuning-fork, make it sound, but not move from its place; while if spent upon a top, would enable the latter to stand upon its point as easily as a person stands on his two feet, and to do other surprising things which otherwise it could not do. One can, without difficulty, form a mechanical conception of the whole series without assuming imponderables or fluids or forces. Mechanical motion only, by pressure, has been transferred in certain di-

rections at certain rates. Suppose, now, that some one should suddenly come upon a spinning top (Fig. 3) while it was standing upon its point, and, as its motion might not be visible, should cautiously touch it. It would bound away with surprising promptness; and, if he were not instructed in the mechanical principles involved, he might fairly well draw the conclusion that it was actuated by other than simple mechanical principles; and, for that reason, it would be difficult to persuade him that there was nothing essentially different in the body that appeared and acted thus, than in a stone thrown into the air: nevertheless, that statement would be the simple truth.

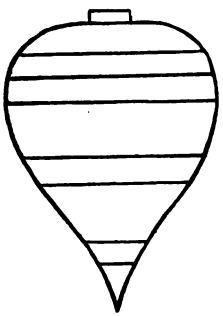


*Fig. 3.*

All of our experience, without a single exception, enforces the proposition that no body moves in any direction, or in any way, except when some other body *in contact* with it impresses its own motion upon it. The action is direct. In Newton's letter to his friend Bentley, he says: "That one body should act upon another through empty space, without the mediation of anything else by and through which

their action and pressure may be conveyed from one to another is to me so great an absurdity that I believe no man who has in philosophical matters a competent faculty of thinking can ever fall into it."

For mathematical purposes, it has sometimes been convenient to treat a problem as if one body could act upon another without any physical medium between them; but such a conception has no degree of rationality, and I know of no one who believes in that as a fact. If this be granted, then our philosophy agrees with our experience, and every body moves because it is pushed, and the mechanical antecedent of every kind of phenomenon is to be looked for in some adjacent body possessing energy; that is, the ability to push or produce pressure.

It must not be forgotten that energy is not a simple factor, but is always a product of two factors, — a mass with a velocity, a mass with a temperature, a quantity of electricity into a pressure, and so on. One may sometimes meet the statement that matter and energy are the two realities; both are spoken of as entities. It is much more philosophical to speak of matter and motion: for in the absence of motion there is no energy, and the energy varies with the amount of motion; and, furthermore, to

understand any manifestation of energy one must inquire what kind of motion is involved. This we do when we speak of mechanical energy as the energy involved in a body having a translatory motion; also, when we speak of heat as a vibratory, and of light as a wave, motion. To speak of energy without stating or implying these distinctions is to speak loosely, and to keep far within the bounds of actual knowledge. To speak thus of a body possessing energy or expending energy, is to imply that the body possesses some kind of motion, and produces pressure upon another body because it has motion. Tait and others have pointed out the fact that what is called potential energy must, in its nature, be kinetic. He says: "Now it is impossible to conceive of a truly dormant form of energy whose magnitude should depend, in any way, upon the unit of time; and we are forced to conclude that potential energy, like kinetic energy, depends (even if unexplained or unimagined) upon motion." All this means that it is now too late to stop with energy as a final factor in any phenomenon; that the *form of motion* which embodies the energy is the factor that determines *what* happens, as distinguished from how *much* happens. Here, then, are to be found the distinctions which have heretofore been called

forces; here is embodied the proof that direct pressure of one body upon another is what causes the latter to move, and that the direction of movement depends on the point of application, with reference to the centre of mass.

It is needful now to look at the other term in the product we call energy; namely, the substance moving, sometimes called matter or mass. It has been mentioned that the idea of a medium filling space was present with Newton; but his gravitation problem did not require that he should consider other factors than masses and distances. The law of gravitation as considered by him was: "Every particle of matter attracts every other particle of matter with a stress which is proportional to the product of their masses, and inversely as the square of the distance between them." Here we are concerned only with the statement that every particle of matter attracts every other particle of matter. Everything, then, that possesses gravitative attraction is matter in the sense in which that term is used in this law. If there be any other substance in the universe that is not thus subject to gravitation, then it is improper to call it matter, otherwise the law should read: "Some particles of matter attract," etc., which will never do.

We are now assured that there is something

else in the universe which has no gravitative property at all; namely, the ether. It was first imagined in order to account for the phenomena of light, which was observed to take about eight minutes to come from the sun to the earth. Then Young applied the wave theory to the explanation of polarization and other phenomena; and, in 1851, Foucault proved experimentally that the velocity of light was less in water than in air, as it should be if the wave theory be true; and this has been considered a crucial experiment which took away the last hope for the corpuscular theory, and demonstrated the existence of the ether as a space-filling medium capable of transmitting light-waves known to have a velocity of 186,300 miles per second. It was called the luminiferous ether, to distinguish it from other ethers which had also been imagined, such as electric ether for electrical phenomena, magnetic ether for magnetic phenomena, and so on — as many ethers as there were different kinds of phenomena to be explained.

It was Faraday who put a stop to the invention of ethers, by suggesting that the so-called luminiferous ether might be the one concerned in all the different phenomena, and who pointed out that the arrangement of iron filings about a magnet was indicative of the direction of the

stresses in the ether. This suggestion did not meet the approval of the mathematical physicists of his day; for it necessitated the abandonment of the conceptions they had worked with, as well as the terminology which had been employed, and made it needful to reconstruct all their work to make it intelligible, — a labor which was the more distasteful as it was forced upon them by one who, although expert enough in experimentation, was not a mathematician, and who boasted that the most complicated mathematical work he ever did was to turn the crank of a calculating-machine; who did all his work, formed his conclusions, and then said: "The work is done; hand it over to the computers."

It has turned out that Faraday's mechanical conceptions were right. Every one now knows of Maxwell's work, which was to start with Faraday's conceptions as to magnetic phenomena, and follow them out to their logical conclusions, applying them to molecules and their reactions upon the ether. Thus he was led to conclude that light was an electro-magnetic phenomenon; that is, that the waves which constitute light and waves produced by changing magnetism were identical in their nature, were in the same medium, travelled with the same velocity, were capable of refraction, and

so on. Now that all this is a matter of common knowledge to-day, it is curious to look back no farther than ten years. Maxwell's conclusions were adopted by scarcely a physicist in the world. Although it was known that inductive action travelled with finite velocity in space, and that an electro-magnet would affect the space about it practically inversely as the square of the distance, and that such phenomena as are involved in telephonic induction between circuits could have no other meaning than the one assigned by Maxwell, yet nearly all the physicists failed to form the only conception of it that was possible, and waited for Hertz to devise apparatus for producing interference before they grasped it. It was even then so new to some, that it was proclaimed to be a demonstration of the existence of the ether itself, as well as a method of producing waves short enough to enable one to notice interference phenomena. It is obvious that Hertz himself must have had the mechanics of wave motion plainly in mind, or he would not have planned such experiments. The outcome of it all is, that we now have experimental proof, as well as theoretical reason, for believing that the ether, once called luminiferous, is concerned in all electric and magnetic phenomena, and that waves set up in it by electro-magnetic actions

are capable of being reflected, refracted, polarized, and twisted, the same as ordinary light-waves can be, and that the laws are applicable to both.

## CHAPTER II

### PROPERTIES OF MATTER AND ETHER

A COMMON conception of the ether has been, that it is a finer-grained substance than ordinary matter, but otherwise so like the latter that the laws found to hold good with matter were as applicable to the ether; and hence the mechanical conceptions formed from experience with the one have been transferred to the other, and the properties belonging to one, such as density, elasticity, etc., have been asserted as properties of the other.

There is so considerable a body of knowledge bearing upon the similarities and dissimilarities of these two entities, that it will be well to compare them. One may then be better able to judge of the propriety of assuming them to be subject to identical laws.

#### 1. MATTER IS DISCONTINUOUS.

It is made up of atoms having dimensions which have been approximately determined to

be in the neighborhood of the one fifty millionth of an inch in diameter. These may have various degrees of aggregation, — practical contact, as in most solid bodies, like the metals and rocks; in molecular groupings, as in water and gases such as hydrogen, oxygen, and so forth, where two, three, or more atoms cohere so strongly as to enable the molecules to act under ordinary circumstances like simple particles. Any or all of these molecules and atoms may be separated by any assignable distance from each other. Thus, in common air the molecules, though rapidly changing their positions, are on the average about two hundred and fifty times their own diameter apart. This is a distance relatively greater than the distance apart of the earth and the moon; for two hundred and fifty times the diameter of the earth will be $8{,}000 \times 250 = 2{,}000{,}000$ miles, while the distance to the moon is but 240,000 miles. The sun is 93,000,000 miles from the earth; and the most of the bodies of the solar system are still more widely separated, Neptune being nearly 3,000 millions of miles from the sun. As for the stars, they are so far separated from us, that, at the present rate of motion in its drift through space, 500 millions of miles in a year, it would take not less than 40,000 years to reach our nearest neighbor, while for the more remote

ones millions of years must be reckoned. This huge space which separates these masses is practically devoid of matter; it is a vacuum.

### THE ETHER IS CONTINUOUS.

The idea of continuity as distinguished from discontinuity may be gained by considering what would be visible by magnification. Water appears to the eye as if it were without pores; but if sugar or salt be put into it, either will be dissolved, and quite disappear among the molecules of the water, as steam does in the air, which shows that there are some unoccupied spaces between the molecules. If a microscope be employed to magnify a minute drop of water, it still shows the same lack of structure as that looked at with the unaided eye. If the magnifying power be the highest, it may reveal a speck as small as the hundred thousandth part of an inch, yet the speck looks no different in character. We know that water is composed of two different kinds of atoms, hydrogen and oxygen; for they can be separated by chemical means, and kept in separate bottles, and again made to combine to form water, having all the qualities that belonged to it before it was decomposed. If a still higher magnifying power were available, we are very sure we should ulti-

mately be able to see the individual water molecules, and recognize their hydrogen and oxygen constituents by their difference in size, rate of movements, and separate them by mechanical methods. What one would see would be something very different in structure from the water as it appears to our eyes. If the ether were similarly to be examined through higher and still higher magnifying powers, even up to infinity, there is no reason for thinking that the last examination would show anything different in structure or quality from that which was examined with low power, or with no microscope at all. This is all expressed by saying that the ether is a continuous substance, without interstices; that it fills space completely, and, unlike gases, liquids, and solids, is incapable of absorbing or dissolving anything.

### 2. MATTER IS LIMITED.

There appears to be a definite amount of it in the visible universe, a definite number of molecules and atoms. How many molecules there are in a cubic inch of air, under ordinary pressure, has been determined, and is represented approximately by a huge number, something like a thousand million million millions.

When the diameter of a molecule has been

measured, as it has been approximately, and found to be about one fifty millionth of an inch, then fifty million in a row would reach an inch, and the cube of fifty million is

125000,000000,000000,000000,

one hundred and twenty-five thousand million million millions. In a cubic foot there will, of course, be 1,728 times that number. One may, if he likes, find how many there may be in the earth and moon, sun and planets; for the dimensions of them are all very well known. Only the multiplication table need be used, and the sum of all these will give how many molecules there are in the solar system. If one should feel that the number thus obtained was not very accurate, he might reflect that if there were ten times as many it would add but another cipher to a long line of similar ones, and would not materially modify it. The point is, that there is a definite, computable number. If one will then add to these the number of molecules in the more distant stars and nebulæ, of which there are visible about 100,000000, making such estimate of their individual size as he thinks prudent, the sum of all will give the number of molecules in the visible universe. The number is not so large but it can be written down in a minute or two.

Those who have been to the pains to do the sum, say it may be represented by 7, followed by ninety-one ciphers. One could easily compute how many molecules so large a space would contain if it were full, and as closely packed as they are in a drop of water; but there would be a finite, and not an infinite, number, and therefore there is a limited number of atoms in the visible universe.

### THE ETHER IS UNLIMITED.

The evidence for this comes to us from the phenomena of light. Experimentally, ether-waves of all lengths are found to have a velocity of 186,000 miles in a second. It takes about eight minutes to reach us from the sun, four hours from Neptune, the most distant planet, and from the nearest fixed stars about three and a half years. Astronomers tell us that some visible stars are so distant that their light requires not less than ten thousand years, and probably more, to reach us, though travelling at the enormous rate of 186,000 miles a second. This means that the whole of the space is filled with this medium. If there were any vacant spaces, the light would fail to get through them, and stars beyond them would become invisible. There are no such vacant spaces; for any part of the heavens shows stars beaming continu-

ously, and every increase in telescopic power shows stars still farther removed than any seen before. The whole of this intervening space must, therefore, be filled with the ether. Some of the waves that reach us are not more than the hundred thousandth of an inch long; so there can be no crack or break or absence of ether from so small a section as the hundred thousandth of an inch in all this great expanse. More than this. No one can think that the remotest visible stars are upon the boundary of space; that if one could get to the most distant star, he could have on one side the whole of space, while the opposite side was devoid of it. The space we know is of three dimensions; and a straight line may be prolonged in any direction to an infinite distance, and a ray of light may travel on for an infinite time, and come to no end, provided the space be filled with ether.

How long the sun and stars have been shining no one knows; but it is highly probable that the sun has existed for not less than 1,000 million years, and has during that time been pouring its rays as radiant energy into space. If, then, in half that time, or 500 millions of years, the light had somewhere reached a boundary to the ether, it could not have gone beyond, but would have been reflected back into the ether-filled space, and such part of the sky

would be light from this reflected light. There is no indication that anything like reflection comes to us from the sky. This is equivalent to saying that the ether fills space in every direction from us to an unlimited distance, and so far is itself unlimited.

### 3. MATTER IS HETEROGENEOUS.

The various kinds of matter we are acquainted with are commonly called the elements. These when combined in various ways exhibit characteristic phenomena which depend upon the kinds of matter, the structure, and motions which are involved. There are some seventy different kinds of this elemental matter which may be identified as constituents of the earth. Many of the same elements have been identified in the sun and stars; such, for instance, as hydrogen, carbon, and iron. Such phenomena lead us to conclude that the kinds of matter elsewhere in the universe are identical with such as we are familiar with, and that elsewhere the variety is as great. The qualities of the elements are permanent; they are not subject to fluctuations, though the qualities of combinations of them may vary indefinitely. The elements, therefore, retain their identity through all kinds of changes.

THE ETHER IS HOMOGENEOUS.

One part is precisely like any other part everywhere and always, and there are no such distinctions in it as correspond with the elemental forms of matter.

### 4. MATTER IS ATOMIC.

That is, there is an ultimate particle of each one of the elements which is practically absolute. The atom retains its identity through all combinations and processes. It may be here or there, move fast or slow, its atomic form persists.

THE ETHER IS NON–ATOMIC.

One might infer from what has already been said about continuity, that the ether could not be constituted of separable particles like masses of matter; for no matter how minute they might be, there would be interspaces and unoccupied spaces which would present us with phenomena which have never been seen. It is the general consensus of opinion among those who have studied the subject, that the ether is not atomic in structure.

### 5. MATTER HAS DEFINITE STRUCTURE.

Every atom of every element is so like every other atom of the same element as to show the same characteristics, — size, weight, chem-

*Fig. 4.*

To make vortex rings (Fig. 4), provide a box with a hole in front and a flexible back of cloth. Saucers containing ammonia and hydrochloric acid will fill the box with dense white fumes. A stroke on the back of the box will expel a vortex ring.

ical activity, vibratory rate, etc., — and thus shows conclusively that the structural form of the elemental particles is the same for each element; for such characteristic reactions as

they exhibit could hardly be if they were mechanically unlike.

Just what form the atoms of an element may be is not very definitely known. The earlier philosophers assumed them to be hard, round particles; but later ones have concluded that such atoms are highly improbable, for they could not exhibit such properties as the elements do exhibit. They have, therefore, dismissed such a conception from consideration. In its place has been substituted a very different idea; namely, that an atom is a vortex ring of ether floating in the ether, as a smoke ring puffed out by a locomotive in still air may float in the air, and show various phenomena.

A vortex ring produced in the air (Fig. 4) behaves in the most surprising manner.

1. It retains its ring form and the same material rotating as it starts with.
2. It can travel through the air easily twenty or thirty feet in a second without disruption.
3. Its line of motion when free is always at right angles to the plane of the ring.
4. It will not stand still unless compelled by some object. If stopped in the air, it will start up itself to travel on without external help.

5. It possesses momentum and energy like a solid body.
6. It is capable of vibrating like an elastic body, making a definite number of such vibrations per second, — the degree of elasticity depending upon the rate of vibration. The swifter the rotation, the more rigid and elastic it is.
7. It is capable of spinning on its own axis, and thus having rotary energy as well as translatory and vibratory.
8. It repels light bodies in front of it, and attracts into itself light bodies in its rear.
9. If projected along parallel with the top of a long table, it will fall upon it every time, as a stone thrown horizontally will fall to the ground.
10. If two rings of the same size be travelling in the same line, and the rear one overtakes the other, the front one will enlarge its diameter, while the rear one will contract its own till it can go through the forward one, when each will recover its original diameter, and continue on in the same direction, but vibrating, expanding, and contracting its diameter with regularity.
11. If two rings be moving in the same line,

but in opposite directions, they will repel each other when near, and thus retard their speed. If one goes through the other, as in the former case, it may quite lose its velocity, and come to a standstill in the air till the other has moved on to a distance, when it will start up in its former direction.

12. If two rings be formed side by side, they will instantly collide at their edges, showing strong attraction.

13. If the collision does not destroy them, they may either break apart at the junction of the collision, and then weld together into a single ring, with twice the diameter, and then move on as if a single ring had been formed, or they may simply bound away from each other; in which case they always rebound *in a plane at right angles* to the plane of collision. That is, if they collided on their sides they would rebound so that one went up and the other down.

14. Three may in like manner collide, and fuse into a single ring.

Such rings formed in air by a locomotive may rise wriggling in the air to the height of several hundred feet, but presently they are

dissolved and disappear. This is because the friction and viscosity of the air robs the rings of their substance and energy. If the air were without friction this could not happen; and the rings would then be persistent, and would retain all their qualities.

Suppose, then, that such rings were produced in a medium without friction, as the ether is believed to be; they would be permanent structures with a variety of properties. They would occupy space, have definite form and dimensions, momentum, energy, attraction and repulsion, elasticity, obey the laws of motion, and so far behave quite like such matter as we know. For such reasons it is thought by some persons to be not improbable that the atoms of matter are minute vortex rings of ether in the ether. That which distinguishes the atom from the ether is the form of motion which is embodied in it; and if the motion simply were arrested, there would be nothing to distinguish the atom that was from the ether it dissolved into. In other words, such a conception makes the atoms of matter *a form of motion of the ether*, and not a created something put into the ether.

### THE ETHER IS STRUCTURELESS.

If the ether be the boundless substance described, it is clear it can have no form as a

whole; and if it be continuous, it can have no minute structure. If not constituted of atoms or molecules, there is nothing descriptive that can be said about it. A molecule or a particular mass of matter could be identified by its form, and thus is in marked contrast with any portion of ether, for it could not be identified in a similar way. One may therefore say that the ether is formless.

### 6. MATTER IS GRAVITATIVE.

The law of gravitation is held as being universal. It states that every particle of matter in the universe attracts every other particle. The evidence for it in the solar system is complete. Sun, planets, satellites, comets, and meteors are all controlled by it in a gravitative way; and the movements of double stars testify to its activity in the more distant bodies of the universe. The attraction does not depend upon the kind of matter, nor the arrangement of molecules or atoms, but upon the amount or mass of matter present; and if it be of a definite kind of matter, as of hydrogen or iron, the gravitative action is proportional to the number of atoms.

### THE ETHER IS GRAVITATIONLESS.

One might infer already that if the ether were structureless, physical laws operative upon such material substances as atoms could not be applicable to it; and so, indeed, all the evidence we have shows that gravitation is not one of its properties. If it were, and it behaved in any degree like atomic structures, it would be found to be denser in the neighborhood of large bodies like the earth, planets, and the sun. Light would be turned from its straight path while travelling in such denser medium, or made to move with less velocity. There is not the slightest indication of any such effect anywhere within the range of astronomical vision.

Gravitation, then, is a property belonging to matter, and not to ether. The impropriety of thinking or speaking of the ether as matter of any kind will be apparent if one reflects upon the significance of the law of gravitation as stated. Every particle of matter in the universe attracts every other particle. If there be anything else in the universe which has no such quality, then it should not be called matter, else the law should read: Some particles of matter attract some other particles, which would be no law at all; for *a real physical law has no exceptions* any more than the multipli-

cation table has. Physical laws are physical relations, and all such relations are quantitative.

### 7. MATTER IS FRICTIONABLE.

A bullet shot into the air has its velocity continuously reduced by the air to which its energy is imparted by making it move out of its way. A railway train is brought to rest by the friction-brake upon the wheels. The translatory energy of the train is transformed into the molecular energy called heat. The steamship requires to propel it fast a large amount of coal for its engines; for the water offers great friction resistance, which must be overcome. Whenever one surface of matter is moved in contact with another surface, there is a resistance called friction, the moving body loses its rate of motion, and will presently be brought to rest unless energy be continuously supplied. This is true for masses of matter of all sizes, and with all kinds of motion. Friction is the condition for the transformation of all kinds of mechanical motions into heat. The test for the amount of friction is the rate of loss of motion. A top will spin some time in the air, because its point is small. It will spin longer on a plate than on the carpet, and longer in a vac-

uum than in the air; for it does not have the air friction to resist it, and there is no kind or form of matter not subject to frictional resistance.

### THE ETHER IS FRICTIONLESS.

The earth is a mass of matter moving in the ether. In the equatorial region the velocity of a point is more than a thousand miles in an hour; for the circumference of the earth is twenty-five thousand miles, and it turns once on its axis in twenty-four hours, which is the length of the day. If the earth were thus spinning in the atmosphere, the latter not being in motion, the wind would blow with ten times hurricane velocity. The friction would be so great that nothing but the foundation rocks of the earth's crust could withstand it, and the velocity of rotation would be reduced appreciably in a relatively short time. The air moves along with the earth as a part of it, and consequently no such frictional destruction takes place; but the earth rotates in the ether with that same rate, and if the ether offered resistance it would react so as to retard the rotation and increase the length of the day. Astronomical observations show that the length of the day has certainly not changed so much as the tenth of a second during the past two thousand years.

The earth also revolves about the sun, having a speed of about nineteen miles in a second, or sixty-eight thousand miles an hour. This motion of the earth and the other planets about the sun is one of the most stable phenomena we know. The mean distance and period of revolution of every planet is unalterable in the long run. If the earth had been retarded by its friction in the ether, the length of the year would have been changed, and astronomers would have discovered it. They assert that a change in the length of a year by so much as the hundredth of a second has not happened during the past thousand years. This, then, is testimony that a velocity of nineteen miles a second for a thousand years has produced no effect upon the earth's motion that is noticeable. Nineteen miles a second is not a very swift astronomical motion; for comets have been known to have a velocity of four hundred miles a second when in the neighborhood of the sun, and yet they have not seemed to suffer any retardation, for their orbits have not been shortened. Some years ago a comet was noticed to have its periodic time shortened an hour or two; and the explanation offered at first was that the shortening was due to friction in the ether, although no other comet was thus affected. The idea was soon abandoned, and to-day there is no astronomical evi-

dence that bodies having translatory motion in the ether meet with any frictional resistance whatever. If a stone could be thrown in interstellar space with a velocity of fifty feet a second, it would continue to move in a straight line with the same speed for any assignable time.

As has been said, light moves with the velocity of 186,000 miles per second, and it may pursue its course for tens of thousands of years. There is no evidence that it ever loses either its wave length or energy. It is not transformed as friction would transform it, else there would be some distance at which light of given wave length and amplitude would be quite extinguished. The light from distant stars would be different in character from that coming from nearer stars. Furthermore, as the whole solar system is drifting in space some 500 millions of miles in a year, new stars would be coming into view in that direction, and faint stars would be dropping out of sight in the opposite direction, — a phenomenon which has not been observed. Altogether, the testimony seems conclusive that the ether is a frictionless medium, and does not transform mechanical motion into heat.

### 8. MATTER IS ÆOLOTROPIC.

That is, its properties are not alike in all directions. Chemical phenomena, crystallization, magnetic and electrical phenomena show, each in their way, that the properties of atoms are not alike on opposite faces. Atoms combine to form molecules; and molecules arrange themselves in certain definite geometric forms, such as cubes, tetrahedra, hexagonal prisms, and stellate forms with properties emphasized on certain faces or ends. Thus quartz will twist a ray of light in one direction or the other, depending upon the arrangement, which may be known by the external form of the crystal. Calc-spar will break up a ray of light into two parts if the light be sent through it in certain directions, but not if in another. Tourmaline polarizes light sent through its sides, and becomes positively electrified at one end while being heated. Some substances will conduct sound or light or heat or electricity better in one direction than in another. All matter is magnetic in some degree, and that implies polarity. If one will recall the structure of a vortex ring, he will see how all the motion is inward on one side, and outward on the other, which gives different properties to the two sides, — a push away from it on one, and a pull toward it on the other.

THE ETHER IS ISOTROPIC.

That is, its properties are alike in every direction. There is no distinction due to position. A mass of matter will move as freely in one direction as in another; a ray of light of any wave length will travel in it in one direction as freely as in any other; neither velocity nor direction is changed by the action of the ether alone.

**9. MATTER IS CHEMICALLY SELECTIVE.**

When the elements combine to form molecules, they always combine in definite ways and in definite proportions. Carbon will combine with hydrogen, but will drop it if it can get oxygen. Oxygen will combine with iron or lead or sodium, but cannot be made to combine with fluorin. No more than two atoms of oxygen can be made to unite with one carbon atom, nor more than one hydrogen with one chlorin atom. There is thus an apparent choice for the kind and number of associates in molecular structure; and the stability of a molecule depends altogether upon the presence in its neighborhood of other atoms for which some of the elements in the molecule have a stronger attraction or affinity than they have for the atoms

they are now combined with. Thus iron is not stable in the presence of water molecules, and it becomes iron oxid; iron oxid is not stable in the presence of hot sulphur, and it becomes an iron sulphid. All the elements are thus selective; and it is by such means that they may be chemically identified.

There is no phenomenon in the ether that is comparable with this. Evidently there cannot be unless there are atomic structures having different characteristics in some degree which the ether is without.

### 10. THE ELEMENTS OF MATTER ARE HARMONICALLY RELATED.

It is possible to arrange the elements in the order of their atomic weights in columns which will show communities of property. Newlands, Mendelleef, Meyer, and others have done this. The explanation for such an arrangement has not yet been forthcoming, but that it expresses a real fact is certain; for in the scheme there are several gaps representing undiscovered elements, the properties of which could be predicted by their associates in the table. Some of these have since been discovered, and their atomic weight and physical properties accord with those predicted.

With the ether such a scheme is quite impossible, for the reason, evident enough, that there are no different things to relate. Every part is just like every other part. Where there are no differences and no distinctions, there can be no relations. The ether is quite without harmonic relations.

### 11. MATTER EMBODIES ENERGY.

So long as the atoms of matter were regarded as hard, round particles, they were assumed to be inert, and only active when acted upon by what were called forces, which were held to be entities of some sort independent of matter. These could pull or push it here or there, but the matter was itself incapable of independent activity. All this is now changed; and we are called upon to consider every atom as being itself a form of energy in the same sense as heat and light are forms of energy, the energy being embodied in particular forms of motion. Light, a wave motion of the ether. An atom, a rotary ring of ether. Stop the wave motion, and the light would be annihilated. Stop the rotation, and the atom would be annihilated for the same reason. As the ray of light is a particular embodiment of energy, and has no existence apart from it, so an atom is to be regarded as *an em-*

*bodiment of energy.* On a previous page it is said that energy is the ability of one body to act upon and move another in some degree. An atom of any kind is not the inert thing it has been supposed to be, for it can do something. Even at absolute zero, when all its vibratory or heat energy is absent, it is still an elastic, whirling body, pulling upon every other atom in the universe with gravitational energy, twisting other atoms into conformity with its own position with its magnetic energy; and if an ether ring acts like the rings which are made in air, it will not stand still in one place, even if no others act upon it, but will start at once, by its own inherent energy, to move in a right line at right angles to its own plane, and in the direction of the whirl inside the ring. Two rings of wood or iron might remain in contact with each other for an indefinite time; but vortex rings will not, but will beat each other away as two spinning tops will do if they touch ever so gently. If they do not thus separate, it is because there are other forms of energy acting to press them together; but such external pressure will be lessened by the ring's own reactions.

It is true that in a frictionless medium like the ether, one cannot at present see how such vortex rings could be produced in it. Certainly

not by any such mechanical methods as are employed to make smoke rings in air; for the friction of the air is the condition for producing them. However they came to be, there is implied the previous existence of the ether, and of energy in some form capable of acting upon it in a manner radically different from any known in physical science.

There is good spectroscopic evidence that in some way elements of different kinds are now being formed in nebulæ; for the simplest show the presence of hydrogen alone. As they increase in complexity, other elements are added, until the spectrum shows most of the elements we know of. It has thus seemed likely, either that most of those called elements are composed of molecular groupings of some fundamental element which by proper physical methods might be decomposed, as one can now decompose a molecule of ammonia or sulphuric acid, or that the elements are now being created by some extra physical process in those far-off regions. In either case an atom is the embodiment of energy in such a form as to be permanent under ordinary physical circumstances, but which if in any manner it should be destroyed, only the form would be lost. The ether would remain, and the energy which was embodied would be distributed in other ways.

THE ETHER IS ENDOWED WITH ENERGY.

The distinction between energy in matter and energy in the ether will be apparent on considering that both the ether and energy in some form must be conceived as existing independent of matter; though every atom were annihilated, the ether would remain, and all the energy embodied in the atoms would be still in existence in the ether. The atomic energy would simply be dissolved. One can easily conceive the ether as the same space-filling, continuous, unlimited medium without an atom in it. Assuming that it is clear that no form of energy with which we deal in physical science would have any existence in it; for every one of those forms, gravitational, thermal, electric, magnetic, or any other, all are the results of the forms of energy in matter. If there were no atoms, there would be no gravitation; for that is the attraction of atoms upon each other. If there were no atoms, there could be no atomic vibration, therefore no heat, and so on for each and all; nevertheless, if an atom be the embodiment of energy, there must have been energy in the ether before any atom existed. One of the properties of the ether is its ability to distribute energy in certain ways, but there is no evidence that of itself it ever transforms energy.

Once a given kind of energy in it, its form does not change; hence, for the apparition of a form of energy like the first vortex ring, there must have been not only energy, but some other agency capable of transforming that energy into a permanent structure. To the best of our knowledge to-day, the ether would be absolutely helpless. Such energy as was active in forming atoms must be called by another name than what is appropriate for such transformations as occur when, for instance, mechanical energy of a bullet is transformed into heat when the target is struck. Behind the ether must be assumed some agency directing and controlling energy in a manner totally different from any operative in what we call physical science. Nothing short of what is called a miracle will do, — an event without a physical antecedent in any way necessarily related to its factors, as is the fact of a stone related to gravity, or heat to an electrical current.

Ether energy is an endowment instead of being an embodiment, and implies antecedents of a superphysical kind.

### 12. MATTER IS AN ENERGY TRANSFORMER.

As each different kind of energy represents some specific form of motion, and *vice versa*,

some sort of mechanism is needful for transforming one kind into another, and molecular structure of one kind or another is essential. The transformation is a mechanical process, and matter in some particular and appropriate form is an essential condition. If heat appears, then its antecedent has been some other form of motion acting upon the substance heated. It may have been mechanical motion of another mass of matter, as when a bullet strikes a target and becomes heated; or it may be friction, as when a car-axle heats when run without proper oiling to reduce friction; or it may be condensation, as when tinder is ignited by condensing the air about it; or chemical reactions when molecular structure is changed, as in combustion; or an electrical current, which implies a dynamo and steam-engine or water-power. If light appears, its antecedent has been impact or friction, condensation or chemical action; and if electricity appears, the same sort of antecedents are present. Whether the one or the other of these forms of energy is developed depends upon what kind of a structure the antecedent energy has acted upon. If radiant energy, so-called, falls upon a mass of matter, what is absorbed is at once transformed into heat, or into electric or magnetic effects: which one of these, depends upon the character of the mechanism upon

which the radiant energy acts; but the radiant energy itself, which consists of ether waves, is traceable back, in every case, to a mass of matter having definite characteristic motions.

One may therefore say with certainty, that every physical phenomenon is a change in the direction or velocity or character of the energy present; and such change has been produced by matter acting as a transformer.

### THE ETHER IS A NON-TRANSFORMER.

It has already been said that the absence of friction in the ether enables light-waves to maintain their identity for an indefinite time, and to an indefinitely great distance. In a uniform homogeneous substance of any kind, any kind of energy which might be in it would continue in it without any change. Uniformity and homogeneity imply similarity throughout, and the necessary condition for transformation is unlikeness. One might not look for any kind of a physical phenomenon which was not due to the presence and activity of some heterogeneity.

As a ray of light continues a ray of light so long as it exists in free ether, so all kinds of radiations of whatever wave length continue identical until they fall upon some mechanical

structure called matter. Translatory motion continues translatory, rotary continues rotary, and vibratory continues to be vibratory; and no transforming change can take place in the absence of matter. The ether is helpless.

### 13. MATTER IS ELASTIC.

It is commonly stated that certain substances, like putty and dough, are inelastic; while some other substances, like glass, steel, and wood, are elastic. This quality of elasticity as manifested in such different degrees depends upon molecular combinations, some of which, as in glass and steel, are favorable for exhibiting it, while others mask it; for the ultimate atoms of all kinds are certainly highly elastic.

The measure of elasticity in a mass of matter is the velocity with which a wave motion will be transmitted through it. Thus, the elasticity of the air determines the velocity of sound in it. If the air be heated, the elasticity is increased, and the sound moves faster. The rates of such sound-conduction range from a few feet in a second to about 16,000, five times swifter than a cannon-ball. In such elastic bodies as vibrate to and fro, like the prongs of a tuning-fork, or give sounds of a definite pitch, the rate of vi-

bration is determined by the size and shape of the body, as well as by their elementary composition. The smaller a body is, the higher its vibratory rate, if it be made of the same material, and the form remains the same. Thus, a tuning-fork that may be carried in the vest pocket may vibrate 500 times a second. If it were only the fifty millionth of an inch in size, but of the same material and form, it would vibrate 30000,000000 times a second; and if it were made of ether instead of steel, it would vibrate as many times faster as the velocity of waves in the ether is greater than it is in steel, and would be as many as 400,000000,000000 times per second. The amount of displacement, or the amplitude of vibration with the pocket fork, might be no more than the hundredth of an inch; and this rate measured as translation velocity would be but five inches per second. If the fork were of atomic magnitude, and should swing its sides one-half the diameter of the atom, or, say, the hundred millionth of an inch, the translational velocity would be equivalent to about eighty miles a second, or a hundred and fifty times the velocity of a cannon-ball, which may be reckoned at about 3,000 feet per second.

That atoms really vibrate at the above rate per second is very certain; for their vibrations

produce ether-waves, the length of which may be accurately measured. When a tuning-fork vibrates 500 times a second, and the sound travels 1,000 feet in the same interval, the length of each wave will be found by dividing the velocity in the air by the number of vibrations, or $1{,}100/500 = 2.2$ feet. In like manner, when one knows the velocity and wave length he may compute the number of vibrations by dividing the velocity by the wave length. Now, the velocity of the waves called light is 186,000 miles a second, and a light-wave may be one forty thousandth of an inch long. The atom that produces the wave must be vibrating as many times per second as the forty thousandth of an inch is contained in 186,000 miles. Reducing this number to inches, we have: —

$$\frac{186{,}000 \times 5{,}280 \times 12}{\frac{1}{40{,}000}} = 400{,}000000{,}000000 \text{ nearly.}$$

This shows that the atoms are minute elastic bodies that change their form rapidly when struck. As rapid as the change is, yet the distance moved through is only one-fifth that of a comet when near the sun, and is therefore easily comparable with other velocities observed in masses of matter.

These vibratory motions due to the elasticity of the atoms is what constitutes heat.

### THE ETHER IS ELASTIC!!

The elasticity of a mass of matter is its ability to recover its original form after that form has been distorted. There is implied that a stress changes its shape and dimensions, which in turn implies a limited mass and relative change of position of parts and some degree of discontinuity. From what has been said of the ether as being unlimited, continuous, and not made of atoms or molecules, it will be seen how difficult, if not impossible, it is to conceive how such a property as elasticity as manifested in matter can be attributed to the ether, which is incapable of deformation, either in structure or form, the latter being infinitely extended in every direction, and therefore formless. Nevertheless, certain forms of motion, such as light-waves, move in it with definite velocity, quite independent of how they originate. This velocity of 186,000 miles a second so much exceeds any movement of a mass of matter, that they can hardly be compared. Thus, if 400 miles per second be the swiftest speed of any mass of matter known, the ether-wave moves $186{,}000 / 400 = 465$ times faster than such comet, and 900,000 times faster than sound travels in air.

It is clear that if this rate of motion depends

upon elasticity, the elasticity must be of an entirely different type from that belonging to matter, and cannot be defined in any such terms as are employed for matter.

If one considers gravitative phenomena, the difficulty is enormously increased. The orbit of a planet is never an exact ellipse, on account of the perturbations produced by the planetary attractions, which depend upon their direction and distance. These, however, are so well known that slight deviations are easily noticed. If gravitative attraction took any such appreciable time to go from one astronomical body to another as does light, it would make very considerable differences in the paths of the planets and the earth. Indeed, if the velocity of gravitation were less than a million times greater than that of light, its effects would have been discovered long ago. It is therefore considered that the velocity of gravitation cannot be less than 186000,000000 miles per second. How much greater it may be no one can guess. Seeing that gravitation is ether pressure, it does not seem probable that its velocity can be infinite. However that may be, the ability of the ether to transmit pressure and various disturbances evidently depends upon properties so different from those that enable matter to transmit disturbances, that

they deserve to be called by different names. To speak of the elasticity of the ether may serve to express the fact that energy may be transmitted at a finite rate in it; but it can only mislead one's thinking if he imagines the process to be similar to energy transmission in a mass of matter. The two processes are incomparable. No other word than elasticity has been suggested, and perhaps it is not needful for most scientific purposes that another should be adopted; but the inappropriateness of the one word for the different phenomena has long been felt.

### 14. MATTER HAS DENSITY.

This quality is exhibited in two ways in matter. In the first, the different elements in their atomic form have different masses or atomic weights. An atom of oxygen weighs sixteen times as much as an atom of hydrogen; that is, it has sixteen times as much matter as determined by weight as the hydrogen atom has, or it takes sixteen times as many hydrogen atoms to make a pound as it takes of oxygen atoms. This is generally expressed by saying that oxygen has sixteen times the density of hydrogen. In like manner iron has fifty-six times the density, and gold one hundred and ninety-six.

The difference is one in the structure of the atomic elements. If one imagines them to be vortex rings, they may differ in size, thickness, and rate of rotation; either of these might make all the observed difference between the elements, including their density. In the second way, density implies compactness of molecules. Thus if a cubic foot of air be compressed until it occupies but half a cubic foot, each cubic inch will have twice as many molecules in it as at first. The amount of air per unit volume will have been doubled, the weight will have been doubled, the amount of matter as determined by its weight will have been doubled; and consequently we say its density has been doubled.

If a bullet or a piece of iron be hammered, the molecules are compacted closer together, and a greater number can be got into a cubic inch when so condensed. In this sense, then, density means the number of molecules in a unit of space, — a cubic inch or cubic centimetre. There is implied in this latter case that the molecules do not occupy all the available space; that they may have varying degrees of closeness; in other words, matter is discontinuous, and therefore there may be degrees in density.

### THE ETHER HAS DENSITY!!

It is common to have the degree of density of the ether spoken of in the same way and for the same reason that its elasticity is spoken of. The rate of transmission of a physical disturbance, as of a pressure or a wave motion in matter, is conditioned by its degree of density; that is, the amount of matter per cubic inch as determined by its weight: the greater the density the slower the rate. So if rate of speed and elasticity be known, the density may be computed. In this way the density of the ether has been deduced by noting the velocity of light. The enormous velocity is supposed to prove that its density is very small, even when compared with hydrogen. This is stated to be about equal to that of the air at the height of two hundred and ten miles above the surface of the earth, where the air molecules are so few that a molecule might travel for sixty millions of miles without coming in collision with another molecule. In air of ordinary density a molecule can, on the average, move no farther than about the two hundred and fifty thousandth of an inch without such collision. It is plain the density of the ether is so far removed from the density of anything we can measure, that it is hardly comparable with such things.

If, in addition, one recalls the fact that the ether is homogeneous, — that is, all of one kind, — and also that it is not composed of atoms and molecules, then degree of compactness and number of particles per cubic inch have no meaning, and the term density, if used, can have no such meaning as it has when applied to matter. There is no physical conception gained from the study of matter that can be useful in thinking of it. As with elasticity, so density is inappropriately applied to the ether; but there is no substitute yet offered.

### 15. MATTER IS HEATABLE.

So long as heat was thought to be some kind of an imponderable thing which might retain its identity whether it were in or out of matter, its real nature was obscured by the name given to it. An imponderable was a mysterious something, like a spirit, which was the cause of certain phenomena in matter. Heat, light, electricity, magnetism, gravitation, were due to such various agencies, that no one concerned himself with the nature of one or the other. Bacon thought that heat was a brisk agitation of the particles of substances, and Count Rumford and Sir Humphry Davy thought they

proved that it could be nothing else; but they convinced nobody. Mayer in Germany, and Joule in England, showed that quantitative relations existed between work done and heat developed; but not until the publication of the book called *Heat as a Mode of Motion*, was there a change of opinion and terminology as to the nature of heat. For twenty years after that it was common to hear the expressions "heat" and "radiant heat," to distinguish between phenomena in matter and what is now called radiant energy radiations, or simply ether-waves. Not until the necessity for distinguishing between different forms of energy and the conditions for developing them, did it become clear to all that a change in the form of energy implied a change in the form of motion that embodied it. The energy called heat energy was proved to be a vibratory motion of molecules; and what happens in the ether as a *result* of such vibrations is no longer spoken of as heat, but as ether-waves. When it is remembered that the ultimate atoms are elastic bodies, and that they will, if free, vibrate in a periodic manner when struck or shaken in any way, just as a bell will vibrate after it is struck, it is easy to keep in mind the distinction between the mechanical form of motion spent in striking, and the vibratory form of the motion

produced by it. The latter is called heat; no other form of motion than that is properly called heat. It is this alone that represents temperature, the rate and amplitude of such atomic and molecular vibrations as constitute change of form. Where molecules like those in a gas have some freedom of movement between impacts, they bound away from each other with varying velocities. The path of such motion may be long or short, depending upon the density or compactness of the molecules; but such changes in position are not heat for a molecule any more than the flight of a musket-ball is heat, though it may be transformed into heat on striking the target.

This conception of heat as the rapid change in form of atoms and molecules due to their elasticity, is a phenomenon peculiar to matter. It implies a body possessing form that may be changed; elasticity, that its changes may be periodic; and degrees of freedom that secure space for the changes. Such a body may be heated. Its temperature will depend upon the amplitude of such vibrations, and will be limited by the maximum amplitude.

### THE ETHER IS UNHEATABLE.

The translatory motion of a mass of matter, big or little, through the ether, is not arrested

in any degree so far as observed; but the internal vibratory motion sets up waves in the ether, the ether absorbs the energy, and the amplitude is continually lessened. The motion has been transferred and transformed; transferred from matter to the ether, and transformed from vibratory to waves travelling at the rate of 186,000 miles per second. The latter is not heat, but the result of heat. With the ether constituted as described, such vibratory motion as constitutes heat is impossible to it, and hence the characteristic of heat motion in it is impossible; it cannot, therefore, be heated. The space between the earth and the sun may have any assignable amount of energy in the form of ether-waves or light, but not any temperature. One might loosely say that the temperature of empty spaces was absolute zero; but that would not be quite correct, for the idea of temperature cannot properly be entertained as applicable to the ether. To say that its temperature was absolute zero would serve to imply that it might be higher, which is inadmissible.

When energy has been transformed, the old name by which the energy was called must be dropped. Ether cannot be heated.

### 16. MATTER IS INDESTRUCTIBLE.

This is commonly said to be one of the essential properties of matter. All that is meant by it, however, is simply this: In no physical or chemical process to which it has been experimentally subjected has there been any apparent loss. The matter experimented upon may change from a solid or liquid to a gas, or the molecular change called chemical may result in new compounds, but the weight of the material and its atomic constituents have not appreciably changed. That matter cannot be annihilated is only the converse of the proposition that matter cannot be created, which ought always to be modified by adding, "by physical or chemical processes at present known." A chemist may work with a few grains of a substance in a beaker or test-tube or crucible, and after several solutions, precipitations, fusions, and dryings, may find by final weighing that he has not lost any appreciable amount; but how much is an appreciable amount? A fragment of matter the ten thousandth of an inch in diameter has too small a weight to be noted in any balance, yet it would be made up of thousands of millions of atoms. Hence, if in the processes to which the substance has been subjected there had been the total annihilation of thousands of

millions of atoms, such phenomenon would not have been discovered by weighing. Neither would it have been discovered if there had been a similar creation or development of new matter. All that can be asserted concerning such events is that they have not been discovered with our means of observation.

The alchemists sought to transform one element into another, as lead into gold. They did not succeed. Presently it was thought to be impossible, and the attempt to do it an absurdity. Lately, however, telescopic observation of what is going on in nebulæ, which has already been referred to, has somewhat modified ideas of what is possible and impossible in that direction. It is certainly possible roughly to conceive how such a structure as a vortex ring in the ether might be formed. With certain polarizing apparatus, it is possible to produce rays of circularly polarized light. These are rays in which the motion is an advancing rotation, like the wire in a spiral spring. If such a line of rotations in the ether were flexible, and the two ends should come together, there is reason for thinking they would weld together, in which case the structure would become a vortex ring, and be as durable as any other. There is reason for believing, also, that somewhat similar movements are always present in a magnetic field;

and though we do not know how to make them close up in the proper way, it does not follow that it is impossible for them to do so.

The bearing of all this upon the problem of transmutation of elements is evident. No one now will venture to deny its possibility as strongly as it was denied a generation ago. It will also lead one to believe rather gently that matter is indestructible. Assuming the vortex-ring theory of atoms to be true, if in any way such a ring could be cut or broken, there would not remain two or more fragments of a ring or atom. The whole would at once be dissolved into the ether. The ring and rotary energy that constituted it an atom would be destroyed, but not the substance it was made of, nor the energy which was thus embodied. For long times the philosophers have argued, and common-sense has agreed, that an atom which could not be ideally broken into two parts was impossible, that one could at any rate think of half an atom as a real objective possibility. This vortex-ring theory shows easily how possible it is to-day to think what once was philosophically incredible. It shows that metaphysical reasoning may be never so clear and apparently irrefragable, yet for all that it may be very unsound. The trouble does not come so much from the logic as from the assumption upon which the

logic is founded. In this particular case the assumption was, that the ultimate particles of matter were hard, irrefragable somethings, without necessary relations to anything else or to energy, and irrefragable only because no means had been found of breaking them.

The destructibility or indestructibility of the ether cannot be considered from the same standpoint as that for matter, either ideally or really. Not ideally, because we are utterly without any mechanical conceptions of the substance upon which one can base either reason or analogy; and not really, because we have no experimental evidence as to its nature or mode of operation. If it be continuous, there are no interspaces; and if it be illimitable, there is no unfilled space anywhere. Furthermore, one might infer that if in any way a portion of the ether could be annihilated, what was left would at once fill up the vacated space so there would be no record left of what had happened. Apparently its destruction would be the destruction of a substance, which is a very different thing from the destruction of a mode of motion. In the latter, only the form of the motion need be changed to completely obliterate every trace of the atom. In the former, there would need to be the destruction of both substance and energy; for it is certain, for reasons yet to

be attended to, that the ether is saturated with energy.

One may, without mechanical difficulties, imagine a vortex ring destroyed. It is quite different with the ether itself; for if it were destroyed in the same sense as the atom of matter, it would be changed into something else which is not ether, a proposition which assumes the existence of another entity, the existence for which is needed only as a mechanical antecedent for the ether. The same assumption would be needed for this entity as for the ether; namely, something out of which it was made, and this process of assuming antecedents would be interminable. The last one considered would have the same difficulties to meet as the ether has now. The assumption that it was in some way and at some time created is more rational, and therefore more probable, than that it either created itself, or that it always existed. Considered as the underlying stratum of matter, it is clear that changes of any kind in matter can in no way affect the quantity of ether.

### 17. MATTER IS INERTIATIVE.

The resistance that a mass of matter opposes to a change in its position, or rate and direction

of movement, is called inertia. That it should actively oppose anything has been already pointed out as reason for denying that matter is inert; but inertia is the measure of the reaction of a body when it is acted upon by pressure from any source tending to disturb its condition of either rest or motion. It is the equivalent of mass, or the amount of matter as measured by gravity, and is a fixed quantity for the atom, is as inherent as any other quality, and belongs to the ultimate atoms and every combination of them. It implies the ability to absorb energy, for it requires as much energy to bring a moving body to a standstill as was required to give it its forward motion.

Both rotary and vibratory movements are opposed by the same property. A grindstone, a tuning-fork, and an atom of hydrogen require, to move them in their appropriate ways, an amount of energy proportionate to their mass or inertia, which energy is again transformed, through friction, into heat, and radiated away.

One may say that inertia is the measure of the ability of a body to transfer or transform mechanical energy. The meteorite that falls upon the earth to-day gives, on its impact, the same amount of energy it would have given if it had struck the earth ten thousand years ago. The inertia of the meteor has persisted, not as

energy, but as a factor of energy. We commonly express the energy of a mass of matter by $mv^2/2$, where $m$ stands for the mass and $v$ for its velocity. We might as well, if it were as convenient, substitute inertia for mass, and write the expression $iv^2/2$; for the mass, being measured by its inertia, is only the more common and less definitive word for the same thing. The energy of a mass of matter is, then, proportional to its inertia, because inertia is one of its factors. Energy has often been treated as if it were an objective thing, an entity and a unity: but such a conception is evidently wrong; for, as has been said before, it is a product of two factors, either of which may be changed in any degree if the other be changed inversely in the same degree. A cannon-ball weighing 1,000 pounds, and moving 100 feet per second, will have 1,560000 foot-pounds of energy; but a musket-ball weighing an ounce will have the same amount when its velocity is 40,000 feet per second. Nevertheless, another body acting upon either bullet or cannon-ball, tending to move either in some new direction, will be as efficient while those bodies are moving at any assignable rate as when they are quiescent; for the change in direction will depend upon the inertia of the bodies, and that is constant.

The common theory of an inert body is one

that is wholly passive, having no power of itself to move or do anything except as some agency outside itself compels it to move in one way or another, and thus endows it with energy. Thus, a stone or an iron nail are thought to be inert bodies in that sense; and it is true that either of them will remain in one place for an indefinite time, and move from it only when some external agency gives them impulse and direction. Still, it is known that such bodies will roll down-hill if they will not roll up, and it has itself as much to do with the down-hill movement as the earth has; that is, it attracts the earth as much as the earth attracts it. If one could magnify the structure until the molecules were individually visible, every one of them would be seen to be in intense activity, changing its form and relative position an enormous number of times per second in undirected ways. No two such molecules move in the same way at the same time; and as all the molecules cohere together, their mutual motions in different directions balance each other, so the body as a whole does not change its position, not because there is no moving agency in itself, but because the individual movements are scattering, and not in a common direction. An army may remain in one place for a long time. To one at a distance it is quiescent, inert. To one in the camp

there is abundant sign of activity; but the movements are individual movements, some in one direction and some in another, and often changing. The same army on the march has the same energy, the same rate of individual movement, but all have a common direction; it moves as a whole body into new territory. So with the molecules of matter. In large masses they appear to be inert, and to do nothing, and to be capable of doing nothing. That is only due to the fact that their energy is undirected, not that they can do nothing. The inference that if quiescent bodies do not act in particular ways they are inert, and cannot act in any kind of a way, is a wrong inference. An illustration may perhaps make this point plainer. A lump of coal will be still as long as anything if it be undisturbed. Indeed, it has thus lain in a coal-bed for millions of years probably; but if coal be placed where it can combine with oxygen, it forthwith does so, and during the process yields a large amount of energy in the shape of heat. One pound of coal in this way gives out 14,000 heat units, which is the equivalent of 11,000,000 foot-pounds of work, and if it could be all utilized, would furnish a horse-power for five and a half hours. Can any inert body weighing a pound furnish a horse-power for half a day? And can a body give out what

it has not got? Are gunpowder and nitroglycerine inert? Are bread and butter, and foods in general, inert because they will not push and pull as a man or a horse may? All have energy, which is available in certain ways and not in others; and whatever possesses energy available in any way is not an ideally inert body.

Lastly, how many inert bodies together will it take to make an active body? If the question be absurd, then all the phenomena witnessed in bodies large or small are due to the fact that the atoms are not inert, but are immensely energetic; and their inertia is the measure of their rates of exchanging energy.

### THE ETHER IS INERTIATIVE CONDITIONALLY.

A moving mass of matter is brought to rest by friction because it imparts its motion at some rate to the body it is in contact with. Generally the energy is transformed into heat, but sometimes it appears as electrification. Friction is only possible because one or both of the bodies possess inertia. That a body may move in the ether for an indefinite time without losing its velocity has been stated as reason for believing the ether to be frictionless. If it be frictionless, then it is without inertia, else the

energy of the earth and of a ray of light would be frittered away. A ray of light can only be transformed when it falls upon molecules which may be heated by it. As the ether cannot be heated, and cannot transform translational energy, it is inertialess for *such* a form of motion and its embodied energy.

It is not thus with other forms of energy than the translational. Atomic and molecular vibrations are so related to the ether that they are transformed into waves, which are conducted away at a definite rate. This shows that such property of inertia as is possessed by the ether is selective, and not like that of matter, which is equally inertiative under all conditions. Similarly with electric and magnetic phenomena: it is capable of transforming the energy which may reside as stress in the ether; and other bodies moving in the space so affected meet with frictional resistance, for they become heated if the motion be maintained. On the other hand, there is no evidence that the body which produces the electric or magnetic stress suffers any degree of friction on moving in precisely the same space. A bar magnet, rotating on its longitudinal axis, does not disturb its own field; but a piece of iron revolving near the magnet will not only become heated, but will heat the stationary magnet. Much experimen-

tal work has been done to discover, if possible, the relation of a magnet to its ether field. As the latter is not disturbed by the rotation of the magnet, it has been concluded that the field does not rotate; but as every molecule in the magnet has its own field, independent of all the rest, it is mechanically probable that each such field does vary in the rotation, but among the thousands of millions of such fields the average strength of the field does not vary within measurable limits. Another consideration is, that the magnetic field itself when moved in space suffers no frictional resistance. There is no magnetic energy wasted through ether inertia. These phenomena show that whether or not the ether exhibits the quality called inertia depends upon the kind of matter and the kind of motion it has.

### 18. MATTER IS MAGNETIC.

The ordinary phenomenon of magnetism is shown by bringing a piece of iron into the neighborhood of a so-called magnet, where it is attracted by the latter, and, if free to move, will go to and cling to the magnet. A delicately suspended magnetic needle will be affected appreciably by a strong magnet at the distance of several hundred feet. As the strength of

such action varies inversely as the square of the distance from the magnet, it is evident there can be no absolute boundary to it. At a distance from an ordinary magnet, it becomes too weak to be detected by our methods, not that there is a limit to it. It is customary to think of iron as being peculiarly endowed with magnetic quality, but all kinds of matter possess it in some degree. Wood, stone, paper, oats, sulphur, and all the rest, are attracted by a magnet, and will stick to it if the magnet be a strong one. Whether a piece of iron itself exhibits the property depends upon its temperature; for near 700 degrees it becomes as magnetically indifferent as a piece of copper at ordinary temperature. Oxygen, too, at −200 degrees adheres to a magnet like iron.

In this, as in so many other particulars, how a piece of matter behaves depends upon its temperature; not that the essential qualities are modified in any degree, but temperature interferes with atomic arrangement and aggregation, and so disguises their phenomena.

As every kind of matter is thus affected by a magnet, the manifestations differing but in degree, it follows that all kinds of atoms, all the elements, are magnetic; an inherent property in them as much so as gravitation or inertia, apparently a quality depending upon the struc-

ture of the atoms themselves, in the same sense as gravitation is thus dependent, as it is not a quality of the ether.

An atom must, then, be thought of as having polarity, different qualities on the two sides, and possessing a magnetic field as extensive as space itself. The magnetic field is the stress or pressure in the ether produced by the magnetic body. This ether pressure produced by a magnet may be as great as a ton per square inch. It is this pressure that holds an armature to the magnet. As heat is a molecular condition of vibration, and radiant energy the result of it, so is magnetism a property of molecules, and the magnetic field the temporary condition in the ether which depends upon the presence of a magnetic body. We no longer speak of the wave motion in the ether which results from heat as heat, but call it radiation or ether-waves; and for a like reason the magnetic field ought not to be called magnetism.

### THE ETHER IS NON-MAGNETIC.

A magnetic field manifests itself in a way that implies that the ether structure, if it may be said to have any, is deformed,—deformed in such a sense that another magnet in it tends to set itself in the plane of the stress; that is, the

magnet is twisted into a new position to accommodate itself to the condition of the medium about it. The new position is the result of the reaction of the ether upon the magnet, an ether pressure acting at right angles to the body that produces the stress. Such an action is so anomalous as to suggest the propriety of modifying the so-called third law of motion; viz., action and reaction are equal and opposite, adding that sometimes action and reaction are at right angles.

There is no condition or property exhibited by the ether itself which shows it to have any such characteristic as attraction, repulsion, or differences in stress, except where its condition is modified by the activities of matter in some way. Itself is not attracted or repelled by a magnet; that is, it is not a magnetic body in any such sense as matter in any of its forms is, and therefore cannot properly be called magnetic.

It has been a mechanical puzzle to understand how the vibratory motions called heat could set up light-waves in the ether, on account of the absence of friction. In the endeavor to conceive it, the origin of sound-waves has been in mind, where longitudinal air-waves are produced by the vibrations of a sounding

body, and molecular impact is the antecedent of the waves. The analogy will not apply. The following exposition may be helpful in grasping the idea of such transformation and change of energy from matter to the ether.

Consider a straight bar permanent magnet to be held in the hand. It has its north and south poles and its field, the latter extending in every direction to an indefinite distance. It is to be considered as ether stress of such a sort as to tend to set other magnets in it in new positions. If, at a distance of ten feet, there were a delicately poised magnet needle, every change in the position of the magnet held in the hand would bring about a change in the position of the needle. If the position of the hand magnet were completely reversed, so the south pole faced where the north pole faced before, the field would have been completely reversed, and the poised needle would have been pushed by the field into an opposite position. If the needle were a hundred feet away, the change would have been the same, except in amount. The same might be said if the two were a mile apart, or the distance of the moon, or any other distance; for there is no limit to an ether magnetic field. Suppose the hand magnet to have its direction completely reversed once in a second. The whole field, and the direction of the

stress, would necessarily be reversed as often. But this kind of change in stress is known by experiment to travel with the speed of light, 186,000 miles a second; the disturbance due to the change of position of the magnet will, therefore, be felt in some degree throughout space. In a second and a third it will have reached the moon, and a magnet there will be in some measure affected by it. If there were an observer there with a delicate enough magnet, he could be witness to its changes once a second, for the same reason one in the room could. The only difference would be one of amount of swing. It is, therefore, theoretically possible to signal to the moon with a swinging magnet. Suppose, again, that the magnet should be swung twice a second, there would be formed two waves, each one-half as long as the first. If it should swing ten times a second, the waves would be one-tenth of 186,000 miles long. If, in some mechanical way, it could be rotated 186,000 times a second, the wave would be but one mile long. Artificial ways have been invented for changing this magnetic field as many as 100 million times a second, and the corresponding wave is less than a foot long. The shape of a magnet does not necessarily make it weaker or stronger as a magnet; but if the poles are near together, the magnetic field is denser

between them than when they are separated. The ether stress is differently distributed for every change in the relative positions of the poles.

A common U-magnet, if struck, will vibrate like a tuning-fork, and it gives out a definite pitch. Its poles swing towards and away from each other at uniform rates, and the pitch of the magnet will depend upon its size, thickness, and the material it is made of.

Let ten or fifteen ohms of any convenient-sized wire be wound upon the bend of a commercial U-magnet. Let this wire be connected to a telephone in its circuit. When the magnet is made to sound like a tuning-fork, the pitch will be reproduced in the telephone very loudly. If another magnet with a different pitch be allowed to vibrate near the former, the pitch of the vibrating body will be heard in the telephone; and these show that the changing magnetic field reacts upon the quiescent magnet, and compels the latter to vibrate at the same rate. The action is an ether action, the waves are ether waves, but they are relatively very long. If the magnet makes 500 vibrations a second, the waves will be 372 miles long, the number of times 500 is contained in 186,000 miles. Imagine the magnet to become smaller and smaller, until it is

the size of an atom, the one fifty millionth of an inch. Its vibratory rate would be proportionally increased, and changes in its form would still bring about changes in its magnetic field. But its magnetic field is practically limitless, and the number of vibrations per second is to be reckoned as millions of millions; the waves are correspondingly short, small fractions of an inch. When they are as short as the one thirty-seven thousandth of an inch, they are capable of affecting the retina of the eye, and then are said to be visible as red light. If the vibratory rate be still higher, and the corresponding waves be no more than one sixty-thousandth of an inch long, they affect the retina as violet light; and between these limits there are all the waves that produce a complete spectrum. The atoms, then, shake the ether in this way because they all have a magnetic hold upon the ether, so that any disturbance of their own magnetism, such as necessarily comes when they collide, reacts upon the ether for the same reason that a large magnet acts thus upon it when its poles approach and recede from each other. It is not a phenomenon of mechanical impact or frictional resistance, since neither is possible in the ether.

### 19. MATTER EXISTS IN SEVERAL STATES.

Molecular cohesion exists between very wide ranges. When strong, so if one part of a body is moved the whole is moved in the same way, without breaking continuity or the relative positions of the molecules, we call the body a solid. In a liquid, cohesion is greatly reduced, and any part of it may be deformed without materially changing the form of the rest. The molecules are free to move about each other, and there is no definite position which any need assume or keep. With gases the molecules are without any cohesion; each one is independent of every other one, collides with and bounds away from others as free elastic particles do. Between impacts it moves in what is called its free path, which may be long or short as the density of the gas be less or greater.

These differing degrees of cohesion depend upon temperature; for if the densest and hardest substances are sufficiently heated they will become gaseous. This is only another way of saying that the states of matter depend upon the amount of molecular energy present. Solid ice becomes water by the application of heat. More heat reduces it to steam; still more decomposes the steam molecules into oxygen and hydrogen molecules; and, lastly, still more

heat will decompose these molecules into their atomic state, complete dissociation. On cooling, the process of reduction will be reversed until ice has been formed again.

Cohesive strength in solids is increased by reduction of temperature, and metallic rods become stronger the colder they are.

No distinction is now made between cohesion and chemical affinity; and yet at low temperatures chemical action will not take place, which phenomenon shows there is a distinction between molecular cohesion and molecular structure. In molecular structure, as determined by chemical activity, the molecules and atoms are arranged in definite ways, which depend upon the rate of vibrations of the components. The atoms are set in definite positions to constitute a given molecule. But atoms or molecules may cohere for other reasons, gravitative or magnetic, and relative positions would be immaterial. In the absence of temperature a solid body would be solider and stronger than ever, while a gaseous mass would probably fall by gravity to the floor of the containing vessel like so much dust. The molecular structure might not be changed, for there would be no agency to act upon it in a disturbing way.

THE ETHER HAS NO CORRESPONDING STATES.

Degrees of density have already been excluded, and the homogeneity and continuity of the ether would also exclude the possibility of different states at all comparable with such as belong to matter. As for cohesion, it is doubtful if the term ought to be applied to such a substance. The word itself seems to imply possible separateness; and if the ether be a single indivisible substance, its cohesion must be infinite, and is therefore not a matter of degree. The ether has sometimes been considered as an elastic solid; but such solidity is comparable with nothing we call solid in matter, and the word has to be defined in a special sense in order that its use may be tolerated at all. In addition to this, some of the phenomena exhibited by it, such as diffraction and double refraction, are quite incompatible with the theory that the ether is an elastic solid. The reasons why it cannot be considered as a liquid or gas have been considered previously.

The expression *states of matter* cannot be applied to the ether in any such sense as it is applied to matter; but there is one sense when possibly it may be considered applicable. Let it be granted that an atom is a vortex ring of ether in the ether, then the state of being in

ring rotation would suffice to differentiate that part of the ether from the rest, and give to it a degree of individuality not possessed by the rest; and such an atom might be called a state of ether. In like manner, if other forms of motion, such as transverse waves, circular and elliptical spirals, or other kinds of waves, exist in the ether, then such movements give special character to the part thus active, and it would be proper to speak of such states of the ether; but even thus the word would not be used in the same sense as it is used when one speaks of the states of matter as being solid, liquid, and gaseous.

### 20. SOLID MATTER CAN MAINTAIN A SHEARING-STRESS; LIQUIDS AND GASES CANNOT.

A sliding-stress applied to a solid deforms it to a degree which depends upon the stress and the degree of rigidity the body has. Thus, if the hand be placed upon a closed book lying on the table, and pressure be so applied as to move the upper side of the book, but not the lower, the book is said to be subject to a shearing-stress. If the pressing hand has a twisting motion, the book will be warped. Any solid may be thus sheared or warped, but neither liquids nor gases can be so affected. Molecu-

lar cohesion makes it possible in the one, and the lack of it impossible in the others. The solid can maintain such a deformation indefinitely long if the pressure does not rupture its molecular structure.

### THE ETHER CAN MAINTAIN A SHEARING-STRESS.

The phenomena in a magnetic field show that the stress is of such a sort as to twist into a new directional position the body upon which it acts, as exhibited by a magnetic needle; also as indicated by the transverse vibrations of the ether waves; and again by the twist given to plane polarized light when moving through a magnetic field. These are all interpreted as indicative of the direction of ether stress, as being similar to a shearing-stress in solid matter. The fact has been adduced to show the ether to be a solid; but such a phenomenon is certainly incompatible with a liquid or gaseous ether. This kind of stress is maintained indefinitely about a permanent magnet; and the mechanical pressure which may result from it is a measure of the strength of the magnetic field, and may exceed a thousand pounds per square inch.

### 21. OTHER PROPERTIES OF MATTER.

There are many secondary qualities exhibited by matter in some of its forms, such as hardness, brittleness, maleability, color, etc.; and the same ultimate element may exhibit itself in the most diverse ways, as is the case with carbon, which exists as lampblack, charcoal, graphite, jet, anthracite, and diamond, ranging from the softest to the hardest of known bodies. Then, it may be black or colorless. Gold is yellow, copper red, silver white, chlorine green, iodine purple. The only significance any or all of such qualities have for us here is, that the ether exhibits none of them. There is neither hardness nor brittleness nor color nor any approach to any of the characteristics for the identification of elementary matter.

### 22. SENSATION DEPENDS UPON MATTER.

However great the mystery of the relation of body to mind, it is quite true that the nervous system is the mechanism by and through which all sensation comes, and that in our experience, in the absence of nerves there is neither sensation nor consciousness. The nerves themselves are but complex chemical struc-

tures; the molecular constitution is said to embrace as many as twenty thousand atoms, chiefly carbon, hydrogen, oxygen, and nitrogen. There must be continuity of this structure too; for to sever a nerve is to paralyze all beyond. If all knowledge comes through experience, and all experience comes through the nervous system, the possibilities depend upon the mechanism each individual is provided with for absorbing from his environment what energies there are that can act upon the nerves. Touch, taste, and smell imply contact; sound has greater range; and sight has the immensity of the universe for its field. The most distant but visible star acts through the optic nerve to present itself to consciousness. It is not the ego that looks out through the eyes, but it is the universe that pours in upon the ego.

Again, all the known agencies that act upon the nerves, whether for touch or sound or sight, imply matter in some of its forms and activities to adapt the energy to the nervous system. The mechanism for the perception of light is complicated. The light acts upon a sensitive surface, where molecular structure is broken up; and this disturbance is in the presence of nerve terminals, and the sensation is not in the eye, but in the sensorium. In like manner for all the rest; so one may fairly say that matter is

the condition for sensation, and in its absence there would be nothing we call sensation.

### THE ETHER IS INSENSIBLE TO NERVES.

The ether is in great contrast with matter in this particular. There is no evidence that in any direct way it acts upon any part of the nervous system or upon the mind. It is probable that this lack of relation between the ether and the nervous system is the chief reason why its discovery was so long delayed, as the mechanical necessities for it even now are felt only by such as recognize continuity as a condition for the transmission of energy of whatever kind it may be. Action at a distance contradicts all experience, is philosophically incredible, and is repudiated by every one who once perceives that energy has two factors, substance and motion.

Here is presented a list of twenty-two of the known properties of matter contrasted with those exhibited by the ether. In none of them are the properties of the two identical, and in most of them what is true for one is not true for the other. They are not simply different; they are incomparable.

From the necessities of the case, as knowl-

edge was acquired, and terminology was essential for making distinctions, the ether has been described in terms applicable to matter; hence such terms as mass, solidity, elasticity, density, rigidity, etc., which have a definite meaning, and convey definite mechanical conceptions when applied to matter, have no corresponding meaning, and convey no such mechanical conceptions, when applied to the ether. It is certain that they are inappropriate, and that the ether and its properties cannot be described in terms applicable to matter. Mathematical considerations derived from the study of matter have no advantage, and are not likely to lead us to a knowledge of the ether.

Only a few have perceived the inconsistency of thinking of the two in the same terms. In his *Grammar of Science*, Professor Karl Pierson says, "We find that our sense-impressions of hardness, weight, color, temperature, cohesion, and chemical constitution, may all be described by the aid of the motions of a single medium, which itself is conceived to have no hardness, weight, color, temperature, nor indeed elasticity of the ordinary conceptual type."

None of the properties of the ether are such as one would or could have predicted if he had had all the knowledge possessed by mankind. Every phenomenon in it is a surprise to us, be-

cause it does not follow the laws which experience has enabled us to formulate for matter. A substance which has none of the phenomenal properties of matter, and is not subject to the known laws of matter, ought not to be called matter. Ether phenomena and matter phenomena belong in different categories; and the ends of science will not be conserved by confusing them, as is done when the same terminology is employed for both.

There are other properties belonging to the ether more wonderful, if possible, than those already mentioned, — its ability to maintain enormous stresses of various kinds without the slightest evidence of interference. There is the gravitational stress, a direct pull between two masses of matter. Between two molecules it is immeasurably small, even when close together; but the prodigious number of them in a bullet brings the action into the field of observation, while between such bodies as the earth and moon or sun the quantity reaches an astonishing figure. Thus, if the gravitative tension due to the gravitative attraction of the earth and moon were to be replaced by steel wires connecting the two bodies to prevent the moon from leaving its orbit, there would be needed four No. 10 steel wires to every square inch upon the earth; and these would be strained

nearly to the breaking-point. Yet this stress is not only endured continually by this pliant, impalpable, transparent medium, but other bodies can move through the same space apparently as freely as if it were entirely free. In addition to this, the stress from the sun and the more variable stresses from the planets are all endured by the same medium in the same space; and apparently a thousand or a million times more would not make the slightest difference. Rupture is impossible.

Electric and magnetic stresses acting parallel or at right angles to the other exist in the same space and to indefinite degrees, neither modifying the direction or amount of either of the others.

These various stresses have been computed to represent energy which, if it could be utilized, each cubic inch of space would yield five hundred horse-power. It shows what a storehouse of energy the ether is. If every particle of matter were to be instantly annihilated, the universe of ether would still have an inexpressible amount of energy left. To draw at will directly from this inexhaustible supply, and utilize it for the needs of mankind, is not a forlorn hope.

The accompanying table presents these contrasting properties for convenient inspection: —

**CONTRASTED PROPERTIES OF MATTER AND THE ETHER.**

| MATTER. | | ETHER. |
|---|---|---|
| 1. Discontinuous . . . | : | Continuous |
| 2. Limited . . . . . | : | Unlimited. |
| 3. Heterogeneous . . | : | Homogeneous. |
| 4. Atomic . . . . . | : | Non-atomic. |
| 5. Definite structure . . | : | Structureless. |
| 6. Gravitative . . . . | : | Gravitationless. |
| 7. Frictionable . . . . | : | Frictionless. |
| 8. Æolotropic . . . . | : | Isotropic. |
| 9. Chemically selective . | : | (————————). |
| 10. Harmonically related . | : | (————————). |
| 11. Energy embodied . . | : | Energy endowed. |
| 12. Energy transformer . | : | Non-transformer. |
| 13. Elastic . . . . . | : | Elastic? |
| 14. Density . . . . . | : | Density? |
| 15. Heatable . . . . . | : | Unheatable. |
| 16. Indestructible . . . | : | Indestructible. |
| 17. Inertiative . . . . | : | Inertiative conditionally. |
| 18. Magnetic . . . . | : | (————————). |
| 19. Variable states . . . | : | (————————). |
| 20. Shearing-stress in solid | : | Shearing-stress maintained. |
| 21. Secondary qualities . | : | (————————). |
| 22. Sensation depends upon | : | Insensible to nerves. |

## CHAPTER III

### TRANSFORMATIONS OF MOTIONS.

So far as we have knowledge to-day, the only factors we have to consider in explaining physical phenomena are: (1) ordinary matter, such as constitutes the substance of the earth and the heavenly bodies; (2) the ether, which is omnipresent; and (3) the various forms of motion, which are mutually transformable in matter, and some of which, but not all, are transformable into ether forms. For instance, the translatory motion of a mass of matter can be imparted to another mass by simple impact, but translatory motion cannot be imparted to the ether, and, for that reason, a body moving in it is not subject to friction, and continues to move on with velocity undiminished for an indefinite time; but the vibratory motion which constitutes heat is transformable into wave motion in the ether, and is transmitted away with the speed of light. The kind of motion which is thus transformed is not even a to-and-fro swing of an atom or molecule, like the swing of a

pendulum-bob, but that due to a change of form of the atoms within the molecule; otherwise there could be no such thing as spectrum analysis. Vibratory motion of the matter becomes undulatory motion in the ether. The vibratory motion we call heat; the wave motion we call sometimes radiant energy, sometimes light. Neither of these terms is a good one, but we now have no others.

It is conceded that it is not proper to speak of the wave motion in the ether as *heat:* it is also admitted that the ether is not heated by the presence of the wave; or, in other words, the temperature of the ether is absolute zero. Matter only can be heated. But the ether-waves can heat other matter they may fall on; so there are three steps in the process, and two transformations: (1) vibrating matter; (2) waves in the ether; (3) vibration in other matter. Energy has been transferred indirectly. What I want to impress in this is, *when a form of energy in matter is transformed in any manner so as to lose its characteristics, it is not proper to call it by the same name after the transformation as before;* and this we do in all cases when the transformation is from one kind in matter to another kind in matter. Thus, when a bullet is shot against a target, before it strikes, it has what we call mechanical energy, and we meas-

ure that in foot-pounds; after it has struck the target, the transformation is into heat, and this has its mechanical equivalent, but is not called mechanical energy, nor are the motions which embody it similar. The mechanical ideas in these phenomena are easy to grasp. They apply to the phenomena of the mechanics of large and small bodies, to sound, to heat, and to light, as ordinarily considered; but they have not been applied to electric phenomena, as they evidently should be, unless it be held that such phenomena are not related to ordinary phenomena, as the latter are to one another.

When we would give a complete explanation of the phenomena exhibited by, say, a heated body, we need to inquire as to the antecedents of the manifestation, and also its consequents. Where and how did it get its heat? Where and how did it lose it? When we know every step of those processes, we know all there is to learn about them. Let us undertake the same thing for some electrical phenomena.

First, under what circumstances do electrical phenomena arise?

(1.) *Mechanical*, as when two different kinds of matter are subject to friction.

(2.) *Thermal*, as when two substances in molecular contact are heated at the junction.

(3.) *Magnetic*, as when any conductor is in a changing magnetic field.

(4.) *Chemical,* as when a metal is being dissolved in any solution.

(5.) *Physiological,* as when a muscle contracts.

Each of these has several varieties; and changes may be rung on combinations of them,

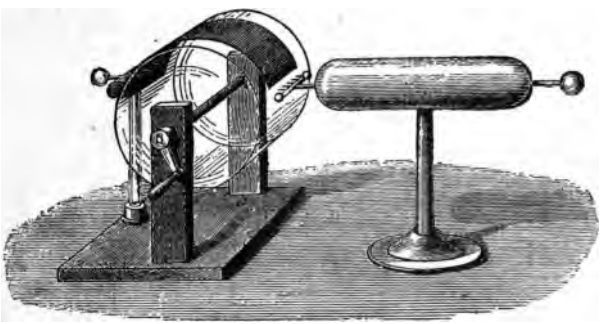


*Fig. 5. Frictional Electrical Machine.*

as when mechanical and magnetic conditions interact.

(1.) In the first case, ordinary mechanical or translational energy is spent as friction, an amount measurable in foot-pounds, and the factors we know, a pressure into a distance. If the surfaces be of the same kind of molecules, the whole energy is spent as heat, and is presently radiated away. If the surfaces are of unlike molecules, the product is a compound one,

part heat, part electrical. What we have turned in we know to be a particular mode of motion. We have not changed the amount of matter involved; indeed, we assume, without specifying and without controversy, that matter is itself indestructible, and the product, whether it be of one kind or another, can only be some form of motion. Whether we can describe it or not is immaterial; but if we agree that heat is vibratory molecular motion, and there be any other kind of a product than heat, it, too, must also be some other form of motion. So, if one is to form a conception of the mechanical origin of electricity, this is the only one he can have, — transformed motion.

*Fig. 6. Thermopile.*

(2.) When heat is the antecedent of electricity, as in the thermopile, that which is turned into the pile we know to be molecular motion of a definite kind. That which comes out of it must be some equivalent motion; and if all that went into it were transformed, then

all that came out would be transformed, call it by what name we will, and let its amount be what it may.

(3.) When a conductor is moved in a magnetic field, the energy spent is measurable in foot-pounds, as before, a pressure into a dis-

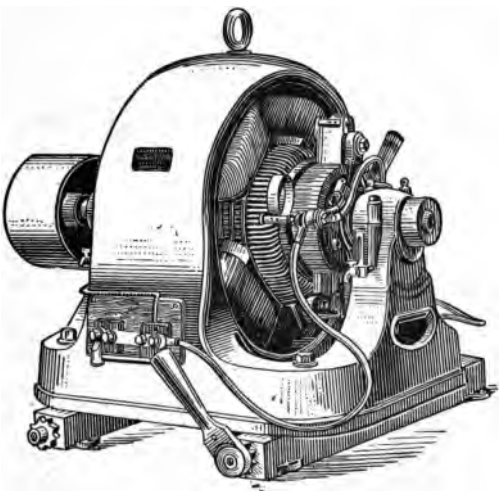


*Fig. 7. Dynamo.*

tance. The energy appears in a new form, but the quantity of matter being unchanged, the only changeable factor is the kind of motion; and that the motion is molecular is evident, for the molecules are heated. Mechanical or mass

motion is the antecedent, molecular heat motion is the consequent; and the way we know there has been some intermediate form is that heat is not conducted at the rate which is observed in such a case. Call it by what name one will, some form of motion has been immediate between the antecedent and the consequent, else we have some other factor of energy to reckon with than ether, matter, and motion.

(4.) In a galvanic battery the source of electricity is chemical action; but what is chemical action? Simply an exchange of the constituents of molecules, a change which involves exchange of energy. Molecules capable of doing chemical work are loaded with energy. The chemical products of battery action are molecules of different constitution, with smaller amounts of energy as measured in calories, or heat units. If the results of the chemical reaction be prevented from escaping by confining them to the cell itself, the whole energy appears as heat, and raises the

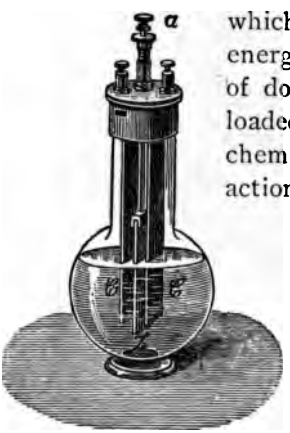



*Fig. 8. Galvanic Battery.*

temperature of the cell. If a so-called circuit be provided, the energy is distributed through it, and less heat is spent in the cell; but whether it be in one place or another, the mass of matter involved is not changed, and the variable factor is the motion, the same as in the other cases. The mechanical conceptions appropriate are the transformation of one kind of motion into another kind by the mechanical conditions provided.

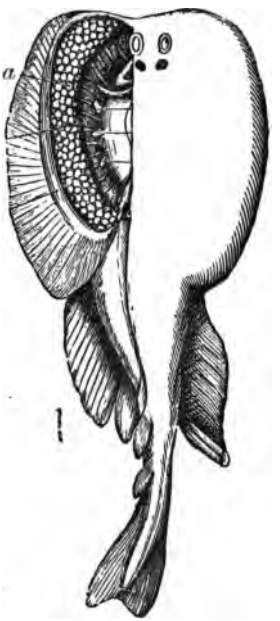



*Fig. 9. Torpedo.*

(5.) Physiological antecedents of electricity are exemplified by the structure and mode of operation of certain muscles, *a*, in the torpedo (Fig. 9) and other electrical animals. The mechanical contraction of them results in an electrical excitation, and, if a proper circuit be provided, in an electric current. The energy of a muscle is de-

rived from food, which is itself but a molecular compound loaded with energy of a kind available for muscular transformation. Bread and butter has more available energy, pound for pound, than has coal, and can be substituted for coal for running an engine. It is not used because it costs so much more. There is nothing different, so far as the factors of energy go, between the food of an animal and the food of an engine. What becomes of the energy depends upon the kind of structure it acts on. It may be changed into translatory, and the whole body moves in one direction; or into molecular, and then appears as heat or electrical energy.

If one confines his attention to the only variable factor in the energy in all these cases, and traces out in each just what happens, he will have only motions of one sort or another, at one rate or another; and there is nothing more mysterious which enters into the processes.

We will turn now to how electricity manifests itself, and what it can do. It may be well to point out at the outset what has occasionally been stated, but which, in my judgment, has not received the philosophical attention it deserves; namely, that electrical phenomena are reversible, — that is, any kind

of a physical process which is capable of producing electricity, electricity is itself able to produce. Thus to name a few: If mechanical motion develops electricity, electricity will produce mechanical motion; the movement of a pith-ball and an electric motor are examples. If chemical action can produce it, it will pro-

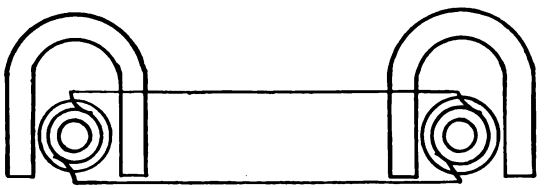



*Fig. 10. Electric Motor.*

duce chemical action, as in the decomposition of water and electroplating. As heat may be its antecedent, so will it produce heat. If magnetism be an antecedent factor, magnetism may be its product. What is called induction may give rise to it in an adjacent conductor; and, likewise, induction may be its effect.

Let us suppose ourselves to be in a building in which a steam-engine is at work. There is fuel, the furnace, the boiler, the pipes, the engine with its fly-wheel turning. The fuel burns in the furnace, the water is superheated in the

boiler, the steam is directed by the pipes, the piston is moved by the steam pressure, and the fly-wheel rotates because of proper mechanism between it and the piston. No one who has given attention to the successive steps in the process is so puzzled as to feel the need of inventing a particular force, or a new kind of matter, or any agency, at any stage of the process, different from the simple mechanical ones represented by a push or a pull. Even if he cannot see clearly how heat can produce a push, he does not venture to assume a genii to do the work, but for the time is content with saying that if he starts with motion in the furnace, and stops with the motion of the fly-wheel, any assumption of any other factor than some form of motion between the two would be gratuitous. He can truthfully say that he understands the *nature* of that which goes between the furnace and the wheel; that it is some sort of motion, the particular kinds of which he might make out at his leisure.

Suppose, once more, that across the highway from this engine-house there is another building, where all sorts of machines — lathes, planers, drills, etc. — are running, but that the source of the power for all this is out of sight, and that one can see no connection between this and the engine on the other side of the

street. Would one need to suppose there was anything mysterious between the two — a force, a fluid, an immaterial something? I am asking the question on the supposition that one was not aware of the shaft that might be between the two buildings, and that it was not obvious on simple inspection how the machines got their motions from the engine. I think no one would be puzzled because he did not know just what the intervening mechanism might be. If the boiler were in the one building, and the engine in the other with the machines, he could see nothing moving between them, even if the steam-pipes were of glass. If matter of any kind were moving, he could not see it there. He would say there *must* be something moving, or pressure could not be transferred from the one place to the other.

Substitute for the furnace and boiler a galvanic battery or a dynamo; for the machines of the shop, one or more motors with suitable wire connections. When the dynamo goes, the motors go; when the dynamo stops, the motors stop; nothing can be seen to be turning or moving in any way between them. Is there any necessity for assuming a mysterious agency, or a force of a *nature* different from the visible ones at the two ends of the line? Is it not certain that the question is, How does the mo-

tion get from the one to the other, whether there be a wire or not? If there be a wire, it is plain that there is motion in it; for it is heated its whole length, and heat is known to be a mode of motion, and every molecule which is thus heated must have had some antecedent motions. Whether it be defined or not, and whether it be called by one name or another, are quite immaterial if one is concerned only with the *nature* of the action, whether it be matter or ether, or motion or abracadabra.

Once more: suppose we have a series of active machines. An arc lamp, radiating light-waves, gets its energy from the wire which is heated, which in turn gets its energy from the

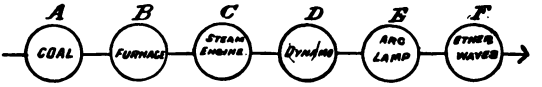



Fig 11

electric current, that from a dynamo, the dynamo from a steam-engine, that from a furnace and the chemical actions going on in it. Let us call the chemical actions *A*, the furnace *B*, the engine *C*, the dynamo *D*, the electric lamp *E*, the ether-waves *F*. (Fig. 11.)

The product of the chemical action of the coal is molecular motion called heat in the fur-

nace. The product of the heat is mechanical motion in the engine. The product of the mechanical motion is electricity in the dynamo. The product of the electric current in the lamp is light-waves in the ether. Nobody hesitates for an instant to speak of the heat as being molecular motion, nor of the motions of the engine as being mechanical; but when we come to the product of the dynamo, which we call electricity, behold! nearly every one says, not that he does not know what it is, but that no one knows. Does any one venture to say he does not know what heat is, because he cannot describe in detail just what goes on in a heated body as it might be described by one who saw with a microscope the movements of the molecules? Let us go back for a moment to the proposition stated early in the

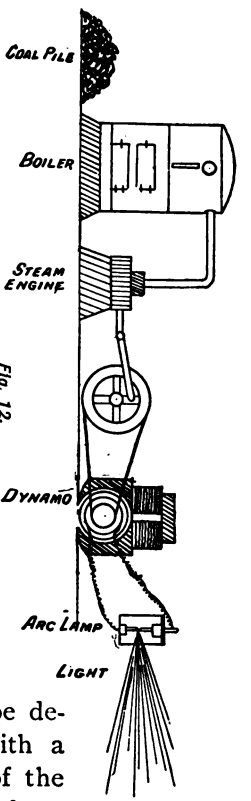



Fig. 12.

address; namely, that if any body of any magnitude moves, it is because some other body in motion, and in contact with it, has imparted its motion by mechanical pressure. Therefore the ether-waves at $F$ (Fig. 11) imply continuous motions of some sort from $A$ to $F$. That they are all motions of ordinary matter from $A$ to $E$ is obvious, because continuous matter is essential for the maintenance of the actions. At $E$ the motions are handed over to the ether, and they are radiated away as light-waves.

A puzzling electrical phenomenon has been what has been called its duality, states which are spoken of as positive and negative. Thus, we speak of the positive plate of a battery, and the negative pole of a dynamo; and another troublesome condition to idealize has been, how it could be that, in an electric circuit, there could be as much energy at the most remote part as at the source. But if one will take a limp rope, eight or ten feet long, tie its ends together, and then begin to twist it at any point, he will see the twist move in a right-handed spiral on the one hand, and in a left-handed spiral on the other, and each may be traced quite round the circuit; so there will be as much twist, as much motion, and as much energy, in one part of the rope as in any other: and if one

chooses to call the right-handed twist positive, and the left-handed twist negative, he will have the mechanical phenomenon of energy distribution and the terminology analogous to what they are in an electric conductor. One may ask,

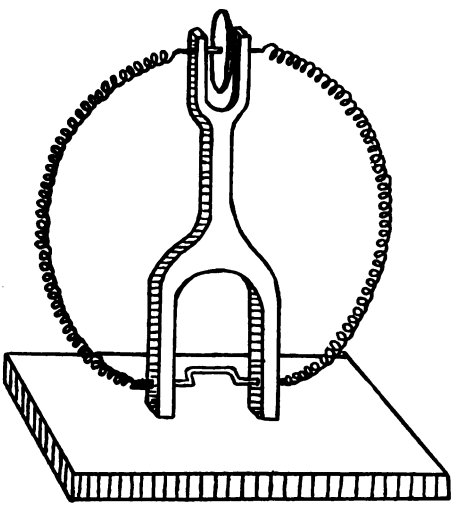


*Fig. 13. Positive and Negative Twist.*

Are not the cases more dissimilar than the mechanical analogy would make them seem to be?

Are there any phenomena which imply that rotation is going on in an electric conductor? There are. An electric arc, which is a current in the air, and is, therefore, less constrained

than it is in a conductor, rotates. Especially marked is this when in front of the pole of a magnet; but the rotation may be noticed in an ordinary arc by looking at it with a stroboscopic disk, rotated so as to make the light to the eye intermittent at the rate of four or five hundred per second. A ray of plane polarized light, parallel with a wire conveying a current, has its plane of vibration twisted to the right or left as the current goes one way or the other through the wire, and to a degree that depends upon the distance it travels; not only that, but if the ray be sent by reflection back through the same field, it is twisted as much more, — a phenomenon which convinces one that rotation is going on in the space through which the ray travels. If the ether through which the ray be sent were simply warped, or in some static stress, the ray, after reflection, would be brought back to its original plane, which is not the case. This rotation in the ether is produced by what is going on in the wire. The ether-waves called light are interpreted to imply that molecules originate them by their vibrations, and that there are as many ether-waves per second as of molecular vibrations per second. In like manner, the implication is the same, that if there be rotations in the ether, they must be produced by molecular rotation, and there must be as

many rotations per second in the ether as there are molecular rotations that produce them. The space about a wire carrying a current is often pictured as filled with whorls indicating this motion (Fig. 14); and one must picture to himself, not the wire as a whole rotating, but each

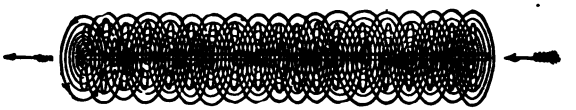


*Fig. 14.*

individual molecule independently. But one is aware that the molecules of a conductor are practically in contact with each other, and that if one for any reason rotates, the next one to it would, from frictional action, cause the one it touched to rotate in the opposite direction, whereas, the evidence goes to show that all rotation is in the same direction.

How can this be explained mechanically? Recall the kind of action that constitutes heat, that it is not translatory action in any degree, but vibratory, in the sense of a change of form of an elastic body; and this, too, of the atoms that make up the molecule, of whatever sort. Each atom is so far independent of every other atom in the molecule that it can vibrate in this way, else it could not be heated. The greater

the amplitude of vibration, the more free space to move in; and continuous contact of atoms is incompatible with the mechanics of heat. There must, therefore, be impact and freedom alternating with each other in all degrees in a heated body. If, in any way, the atoms themselves *were* made to rotate, their heat impacts not only would restrain the rotations, but the energy also of the rotation motion would increase the vibrations; that is, the heat would be correspondingly increased, which is what happens always when an electric current is in a conductor. It appears that the cooler a body is, the less electric resistance it has, and the indications are that at absolute zero there is no resistance; that is, impacts do not retard rotation: but it is also apparent that any current sent through a conductor at that temperature would at once heat it. This is the same as saying that an electric current could not be sent through a conductor at absolute zero.

So far mechanical conceptions are in accordance with electrical phenomena, but there are several others yet to be noted. I have spoken of electrical phenomena as molecular or atomic phenomena; and there is one more in that category which is well enough known, and which is so important and suggestive that I wonder its significance has not been seen by those who

have sought to interpret electrical phenomena. I refer to the fact that electricity cannot be transmitted though a vacuum. An electric arc begins to spread out as the density of the air decreases, and presently it is extinguished. An induction spark that will jump two or three feet in air cannot be made to bridge the tenth of an inch in an ordinary vacuum. A vacuum is a perfect non-conductor of electricity. Is there more than one possible interpretation to this; namely, that electricity is fundamentally a molecular and atomic phenomenon, and in the absence of molecules cannot exist? One may say: "Electrical *action* is not hindered by a vacuum;" which is true, but has quite another interpretation than the implication that electricity is an ether phenomenon.

The heat of the sun in some way gets to the earth, but what takes place in the ether is not heat transmission. There is no heat in space, and no one is at liberty to say or think that there can be heat in the absence of matter. When heat has been transformed into ether-waves it is no longer heat, call it by what name one will. Formerly such waves were called heat-waves; no one properly informed does that now. In like manner, if electrical motions or conditions in matter be transformed, no matter how, it is no longer proper to speak of such

transformed motions or conditions as electricity. Thus, if electrical energy be transformed into heat, no one thinks of speaking of the latter as electrical. If the electrical energy be transformed into mechanical of any sort, no one thinks of calling the latter electrical because of its antecedent. If electrical motions be transformed into ether actions of any kind, why should we continue to speak of the transformed motions or energy as being electrical? Electricity may be the antecedent, in the same sense as mechanical motion of a bullet may be the antecedent of the heat developed when the latter strikes the target; and if it be granted that a vacuum is a perfect non-conductor of electricity, then *it is manifestly improper to speak of any phenomenon in the ether as an electrical phenomenon.* It is from the failure to make this distinction that most of the trouble has come in thinking on this subject. Some have given all their attention to what goes on in matter, and have called that electricity; others have given their attention to what goes on in the ether, and have called that electricity; and some have considered both as being the same thing, and have been confounded. In this sense an arc light is no more an electric light than is that from a tallow candle.

Let us consider what is the relation between an electrified body and the ether about it.

When a body is electrified, the latter at the same time creates an ether stress about it, which is called an electric field. The ether stress may be considered as a warp in the distribution of the energy about the body (Fig. 15) by the new positions given to the molecules by the process of electrification. I have already said that the evidence from other sources is that atoms, rather than molecules, in larger masses, are what affect the ether. One needs

*Fig. 15.*

to inquire for what knowledge we have as to the constitution of matter or of atoms.

There is only one hypothesis to-day that has any degree of probability; that is the vortex-ring theory, which describes an atom as being a vortex ring of ether in the ether. It possesses a definite amount of energy in virtue of the

motion which constitutes it; and this motion differentiates it from the surrounding ether, giving it dimensions, elasticity, momentum, and the possibility of translatory, rotary, and vibratory motions and combinations of them. Without going farther into this, it is sufficient, for a mechanical conception, that one should have so much in mind, as it will vastly help in forming a mechanical conception of reactions between atoms and the ether. An exchange of energy between such an atom and the ether is not an exchange between different kinds of things, but between different conditions of the same thing. Next, it should be remembered that all the elements are magnetic in some degree. This means that they are themselves magnets; and every magnet has a magnetic field, unlimited in extent, which can almost be regarded as a part of itself. If a magnet of any size be moved, its field is moved with it; and if in any way the magnetism be increased or diminished, the field changes correspondingly.

Assume a straight bar electro-magnet in circuit, so that a current can be made intermittent, say, once a second. When the circuit is closed and the magnet is made, the field at once is formed, and travels outwards at the rate of 186,000 miles per second. When the current stops, the field adjacent is destroyed. Another

closure develops the field again, which, like the other, travels outwards; and so there may be formed a series of waves in the ether, each 186,000 miles long, with an electro-magnetic antecedent. If the circuit were closed ten times a second, the waves would be 18,600 miles long; if 186,000 times a second, they would be but one mile long. If 400 million of millions times a second, they would be but the forty-thousandth of an inch long, and would then affect the eye, and we should call them light-waves; but the latter would not differ from the first wave in any particular except in length. As it is proved that such electro-magnetic waves have all the characteristics of light, it follows that they must originate with electro-magnetic action; that is, in the changing magnetism of a magnetic body. This makes it needful to assume that the atoms which originate waves are magnets, as they are experimentally found to be. But how can a magnet, not subject to a varying current, change its magnetic field? The strength or density of a magnetic field depends upon the form of the magnet. When the poles are near together, the field is densest; when the magnet is bent back to a straight bar, the field is rarest or weakest, and a change in the form of the magnet from a U-form to a straight bar would re-

sult in a change of the magnetic field within its greatest limits. A few turns of wire wound about the poles of an ordinary U-magnet, and connected to an ordinary magnetic telephone, will enable one, listening to the latter, to hear the pitch of the former loudly reproduced when the magnet is struck like a tuning-fork so as to vibrate. This shows that the field of the magnet changes at the same rate as the vibrations.

Assume that the magnet becomes smaller and smaller, until it is of the dimensions of an atom; say, for an approximation, the fifty-millionth of an inch. It would still have its field; it would still be elastic and capable of vibration, but at an enormously rapid rate: but its vibration would change its field in the same way, and so there would be formed those waves in the ether which, because they are so short that they can affect the eye, we call light. The mechanical conceptions are legitimate, because based upon experiments having ranges through nearly the whole gamut as waves in ether.

The idea implies that every atom has what may be loosely called an electro-magnetic grip upon the whole of the ether, and any change in the former brings some change in the latter.

Lastly, the phenomenon called induction may be mechanically conceived.

It is well known that a current in a con-

ductor makes a magnet of the wire, and gives it an electro-magnetic field, so that other magnets in its neighborhood are twisted in a way tending to set them at right angles to the wire. Also, if another wire be adjacent to the first, an electric current having an opposite direction is induced in it. Thus : —

Consider a permanent magnet, *A* (Fig. 16), free to turn on an axis in the direction of the arrow. If there be other free magnets, *B* and *C*, in line, they will assume such positions that

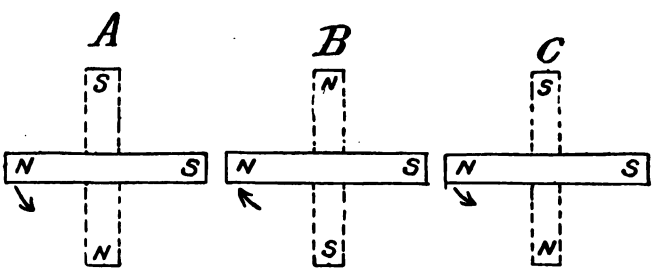



*Fig. 16.*

their similar poles all point one way. Let *A* be twisted to a position at right angles, then *B* will turn, but in the opposite direction, and *C* in similar. That is, if *A* turn in the direction of the hands of a clock, *B* and *C* will turn in opposite directions. These are simply the observed movements of large magnets. Imagine that

these magnets be reduced to atomic dimensions, yet retaining their magnetic qualities, poles and fields. Would they not evidently move in the same way, and for the same reasons? If it be true that a magnet field always so acts upon another as to tend by rotation to set the latter into a certain position with reference to the stress in that field, then, *wherever there is a changing magnetic field, there the atoms are being adjusted by it to new positions.*

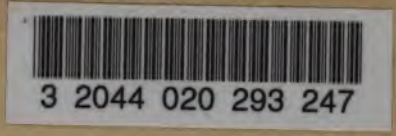
Suppose we have a line of magnetic needles free to turn, hundreds or thousands of them, but disarranged. Let a strong magnetic field be produced at one end of the line. The field would be strongest and best conducted along the magnet line, but every magnet in the line would be compelled to rotate; and if the first were kept rotating, the rotation would be kept up along the whole line. This would be a mechanical illustration of how an electric current travels in a conductor. The rotations are of the atomic sort, and are at right angles to the direction of the conductor.

That which makes the magnets move is inductive magnetic ether stress, but the advancing motion represents mechanical energy of rotation; and it is this motion, with the resulting friction, which causes the heat in a conductor.

What it is proper to emphasize is, that the action in the ether is not electric action, but more properly the result of electro-magnetic action. Whatever name be given to it, and however it comes about, there is no good reason for calling any kind of an ether action electrical.

Electrical action, like magnetic action, begins and ends in matter. It is subject to transformations into thermal and mechanical actions, also into ether stress, — right-handed or left-handed — which, in turn, can similarly affect other matter, but with opposite polarities.

In his *Modern Views of Electricity*, Professor O. J. Lodge warns us, in a way I quite approve, that perhaps, after all, there is no such *thing* as electricity, — that electrification and electric energy may be terms to be kept for convenience; but if electricity, as a term, be held to imply a force, a fluid, an imponderable, or a thing which could be described by some one who knew enough, then it has no degree of probability, for spinning atomic magnets seem capable of developing all the electrical phenomena we meet. It must be thought of as a *condition* and not as an entity.

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